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THE INFORMATION SYSTEMS AND TECHNOLOGY INNOVATION PROCESS: A STUDY USING AN AGENT-BASED APPROACH

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ACRONYMS

ABM……………………………………….………………. Agent-Based Model(ing)

ACE…………………………………………… Agent-based Computational Economics

CAS……………………………………………………….Complex Adaptive System

CASE…………………………………….... Computer Aided Software Engineering

CMOT……………….……… Computational and Mathematical Organization Theory

DM…………………………………………………………………Decision Makers

DOI………………………………………..………………Diffusion Of Innovations

DSS…………………………………………………...……..Decision Support System

EDI……………………………………………………….…… Electronic Data Interchange

ICT..…………………………………… Information and Communication Technologies

ISDA…...…………………………………Information Systems Development Approach

ISF …...…………………………………………………...Information Systems Function

IS/IT……...………………………Information System and or Information Technology

IRI………………………..…Information systems and or technology Related Innovation

KW……………………………………………………………….Knowledge Workers

MCL……………………………………...………………Mean Concordance Level

MOI………………………………………………………Market-Oriented Innovation

OECD………..……………Organisation for Economic Co-operation and Development

R&D……………………………………….……………Research and Development

SME…………………………………………………Small and Medium size Enterprises

SPRU…………………………………………………... Science Policy Research Unit

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Mestrado em: Gestão de Sistemas de Informação

Orientador: Professora Doutora Tanya Vianna de Araújo

Provas concluídas em:

RESUMO

Um modelo abstracto baseado em agentes é utilizado para estudar a inovação em Sistemas de Informação e em Tecnologia de Informação, no plano organizacional, utilizando uma aproximação sócio-cognitiva. A conclusão do estudo indica que o poder dos profissionais conhecedores de tecnologias de informação na decisão de adopção de uma determinada inovação varia com o nível de concordância de ideias entre eles e os decisores, ao mesmo tempo que depende da taxa de depreciação das transacções, conduzindo a uma forte flutuação de poder quando o ambiente é instável.

Palavras-chave: Inovação em Sistemas e Tecnologias de Informação, Adopção de Inovações, Teoria da Complexidade, Simulação, Modelação Baseada em Agentes, Teoria Computacional e Matemática da Organização.

ABSTRACT

An abstract Agent Based Model is used to study Information Systems and Information Technology innovation on an organizational realm, using a socio-cognitive approach. Conclusion is drawn that the power of the knowledge workers in the decision to adopt an IS/IT innovation within an organization varies with the matching level of ideas between them and the top management, while being dependant of the transactions' depreciation rate, leading to a strong fluctuation of power when the environment is unstable.

Key-words: Innovation in Information Systems and Technology, Pre-adoption of Innovations, Complexity Theory, Simulation, Agent-Based Modelling, Computational and Mathematical Organization Theory.

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PREFACE

Nowadays, innovation has become one those words that require careful use, especially in academia, at least until a proper name is given to the science of novelty. One assertion that can easily be accepted is that innovation became popular in almost all fields of enquiry and has displayed an ever increasing appeal to be evoked.

The rhetorical roots of the human discourse, either on political or inexpert use, might generate a background clatter so intense that hamper the scientific efforts in deepening our understanding on innovation.

On the other hand, information systems and associated technology are probably the evidence of the higher level of complexity of the human race, ever since the beginning of History. When useful electronic computers started to emerge, they leveraged the capability of humans to see information being processed, adding automation to pre-existing information systems. Innovation, electronic computers, information systems, which include people, and technology are deeply intertwined as they go hand-in-hand along an evolutionary track. All sort of expectancies were credited to the new ways of treating information, from domination to doomsday. The emergence of new fields of enquiry did not clarify the possibilities of the "new machines", underestimating the notion that it is people that give meaning and reasoning to information mediated through information systems, either automatically or otherwise.

All said it is of particular interest to study the scientific relation between innovation and information systems and technology inside the milieu of an organization, which, by definition, is a human endeavor to pursue some aim.

Lisboa, October 2006

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A Masters Thesis is hardly a personal project. This one was not! Many people contributed either directly or indirectly for this work. Here are just the more relevant for me. Those not mentioned should not feel excluded: it’s just a question of parsimony.

My first words of recognition go to my mother, Joaquina Luísa, who was kept from accomplishing her professional objectives (to become a telephone operator, in the late 30’s) due to the poverty in which she lived in and not because her lack of merit. If this serves as a consolation, your son has always tried to go further, with you in mind, thanks to your remarkable skill in managing that limited budget, the priorities you set, and the values of correctness, honesty and honor you passed to your offspring.

Next, I want to thank my wife, Luísa Margarida, the love of my life, who showed a strong fiber and a very supporting role, dealing with a husband displaying very unstable moods and availability and a very strange routine.

Our kids, Luís and Guilherme, don’t have the faintest idea of what their father was doing. I owe them all the time the den door was closed. Even under these circumstances, their smiles every time I momentarily teased them make me hope that one day they might discover what I was doing.

My supervisor, Professor Tanya Vianna de Araújo, had an absolute decisive role in last year, while I wrote the dissertation. She maintained me focused and kept me from crashing badly. She was always available and willing to share her wisdom with me, making feel the happiest of all the students. I will always be grateful to you, Professor.

Off course, all other teachers in my life must see this thesis as co-product of their work.

Last, but not the least, thank you comrades in the Portuguese Air Force (you know who you are) for your unduly patience you put up with, while working with me for 24 years.

Chapter 1 – INTRODUCTION

In this work we use an agent based model (ABM) and complexity theory as proposed by Carley (1995, 2002) and Axelrod (1999) to investigate a pertinent issue in the management science literature as is the case of the emergence of success in the innovational process with Information Systems and Information Technology (IS/IT). For that purpose, after reviewing the relevant literature, we will introduce, investigate and report the findings about the dynamics of innovation in a virtual organization model or "facetwise model" (Goldberg, 2002). As suggested by Goldberg (2002), we use an agent-based approach and computer simulations as a methodology to "decompose the large problem approximately and intuitively, breaking it into nearly separate subproblems" (Goldberg, 2002, p.16).

The relationship between innovation, IT and performance was investigated using a sample provided by the 1,000 biggest companies in Taiwan[1] by Huang and Liu (2005). The study concluded that investments of IT capital *per se* don't have a significant impact on business performance. However, when one considers the interaction between IT capital and innovation capital, there is a positive impact on performance. Therefore, the authors conclude, a certain level of coordination must be obtained between IS/IT components and intellectual capital[2] in order to create superior performance.

Dawning from a model developed by Daft and Weick (1984), where the authors suggest an organizational interpretation perspective, we make and instantiation of an abstract ABM of market oriented innovation by Araújo and Vilela Mendes (2006), into the field

[1] Taiwan was ranked fourth for growth and competition in the world, according to World Economic Forum (WEF) report in 2004. In the 2006-2007 report Tawain dropped to the 13th place, according to: http://www.weforum.org/pdf/Global_Competitiveness_Reports/Reports/gcr_2006/top50.pdf [Assessed 15 October 2006].

[2] Intellectual capital was taken from Edvinsson and Malone (1997) and is "the possession of the knowledge, applied experience, organizational technology, customer relationships and professional skills that provide company with a competitive edge in the market" (Huang and Liu, 2005, p. 238).

of IS/IT innovation. Daft and Weick (1984) wanted to capture the complexity of the organizational activity and integrate disperse views and empirical facts about the environment in which an organization operates. To reach their purpose, they took a behavioral and cognitive approach[3] to organizational studies and described a model of organizations as interpretation systems. They claimed that every organizational activity and outcome is somewhat dependent on interpretation. Addressing the interpretation of the external environment to key managers, they posited that interpretation occurs before organizational learning and action. They mentioned a three stage feedback loop (Daft and Weick, 1984, p. 286), which includes scanning, or data collection; interpretation, or meaning given to data[4], and learning, as a synonym of action taken. Although they focused on external environment and did not address the internal environment, they stated that strategy formulation (a function of top management), by which a firm develops new products or undertakes new initiatives, and decision making, which is part of the information [flow] process, is associated with interpretation modes (Daft and Weick, 1984, p. 292). The authors clearly stated that once interpretation occurs, or sense making is obtained[5], then a response can be formulated that might include an action. This claim is in line with recent IS/IT innovation research by Swanson and Ramiller (2004), who address the phenomenon inside the organizational innovation research field, adapting the concepts of mindfulness[6] and mindlessness[7] (both represented as

[3] We are aware of other approaches, such as the financial approach, which sees investments in innovation and in IT following the real options paradigm. For some details on this line of enquiry refer to Fichman (2004b) and Wu (2005).
[4] This perspective should be seen as a cognitive approach to the process of decision making. For a more contextualized example, related to creativity and innovation, see Borghini (2005). An information approach, e.g., MacDonald (1995), used as the "dominant paradigm" (Fichman, 2004) defends a hierarchy of data, as symbols, information, as decoded symbols, knowledge, as contextualized information. Other variants exist, for instance, the linkage of all these elements, supported by an IT "architecture" (logical construct) (Zachman, 1987). In the cognitive approach, "interpretation" should be associated with "knowledge" used in the dominant paradigm.
[5] This should be the equivalent of obtaining knowledge, both tacit and or codified.
[6] Mindful decision making is the behaviour displayed by the organizations opposite of the bandwagon phenomenon evident in some other organizations that go with the flock, doing what the others are doing,

ideal types in the Weberian sense – abstract categories used to make empirical comparisons to real cases – and not as a normative type, to include “real organizational conduct”) and developing a model in which the first stage is comprehension. Mindful decisions may include those organizations that “undertake a strong second posture, letting others undertake the initial innovation” (Quinn, 1979), to avoid the pro-innovation bias (Jeyaraj, Rottman and Lacity, 2006), that assumes every innovation as good. In line with this approach, we have adapted a formal model where agents have their characteristics randomly generated, and included a matching mechanism to simulate the similitude of interpretation between the top management and key collaborators in the innovation process.

The activities derived from the interpretation process, in Daft and Weick (1984) model, include, among others, innovation and change. The newness of some processes causes disturbance in the organizational setting, as mentioned by Greve and Taylor (2000). Innovation is seen as a catalyst for producing nonmimetic change in organizations. The catalytic effect is modified by the social and competitive relations between the innovator and a particular organization. They also argue that the decision making process is at the core of the deliberation by top managers either to imitate or innovate. The decision making has a cognitive basis, as the managers become comfortable or not with the information they possess. If they feel that they need to obtain new information then a search is launched using a particular heuristic.

Fuglsang and Sundbo (2005) call this interpretation of the environments the foundation of the change process. Much attention is captured by the literature on external scanning or on the generic process of innovation, developed by Bessant (2005). Empirical work

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by critically analyzing a firms unique circumstances and discriminate choices accordingly, to obtain a better fit (Fiol and O’Connor, 2003, p. 59), cited in Swanson and Ramiller (2004, p. 559).

[7] Mindless in an organizational context is when an organization gives up the attention to its specifics, under the conditions that can manifest either isolated or in combination, such as: attention deferral, contextual insensitivity, and institutional pre-emption (Swanson and Ramiller, 2004, p. 564).

shows that a firm's internal characteristics are perceived by top management to be at least as important for gathering information as the external information (Walters et al., 2003, p. 493).

Admitting that it is somewhat an "arbitrary interpretation imposed on organized activity" (Daft and Weick, 1984) and as a result of our intuition (Goldberg, 2002, p. 26) and knowledge from the Araújo and Vilela Mendes (2006) model, we developed our own model, as an instantiation of the latter.

In Daft and Weick's (1984) model the authors assumed that the greatest weakness of their model was the Thorngate's (1976) postulate of commensurate complexity. This postulate says that, in theory construction, "it is impossible for a theory of social behaviour to be simultaneously general, accurate, and simple". This normally leads the researchers to make tradeoffs among the characteristics of the theories. Daft and Weick (1984) admit that their theory is not accurate, while being general and simple. We equally use the inherently uncertainty of the numerical random generation as an attempt to produce accuracy, bearing in mind that the real trade off is in the fidelity of the model, not in the theory, since the solutions must come within some arbitrary value of a global or near global solution, as shown by Goldberg (2002), usually mentioned as "error", thus producing "inaccurate" outcomes.

Since we are using a formal model in order to test organizational theory, we clearly situate our study in the Computational and Mathematical Organization Theory (CMOT), as suggested by Carley (1995). This author states that the community that does research in this area has an interdisciplinary background and shares a theoretical perspective of organizations as "collections of processes and intelligent adaptive agents that are task oriented, socially situated, technologically bound, and continuously changing" (Carley, 1995, p. 39), within the behavioral stream that see the internal organizational processes interact among themselves and with the external environmental, consequently affecting and be affected by it. As a methodological orientation, the community uses "both computational (e.g., simulation, emulation, expert systems, computer assisted numerical analysis) and mathematical (e.g., formal logic, matrix algebra, network analysis, discrete and continuous functions)" (Carley, 1995, p. 39). The research in this area is aggregated around four sub-fields: organizational design, organizational learning, organizations and information technology, and organizational evolution and change. In 1995, the most cumulative stream was the design, immediately followed by the learning organizational perspectives. More than a decade over, things might have changed as the other streams were stuffed by a prolific community around the world.

The visionary advancement of a "learning organization information system" (LOIS) was symptomatic and could be described as "a scheme to operate a form of corporate memory, gathering and distributing data, information and knowledge across the organization" (Williamson and Iliopoulos, 2001).

Without addressing any other specific stream of research in our work because we are envisioning all of them, we remain focused on the words of Carley (1995, p.39): "formal approaches are particularly valuable to all these areas given the complex adaptive nature of organizational agents and the complex dynamic nature of the environment faced by agents and organizations".

Formal models have been included in the Speech Act-Based Approach[8] to IS development by Iivari, Hirschheim and Klein (1998). This approach views IS as social systems technically implemented and human beings as dominantly voluntaristic but

[8] Developed in North America and in Scandinavia is an attempt to understand and model the rich meanings exchanged in ordinary conversation. Both streams have their roots in Searle's philosophy of language. According to this theory speech acts are basic units, classified by their illocutionary point into five categories: assertives, commissives, directives, declaratives, and expressives (Iivari, Hirschheim and Klein, 1998, p. 169).

including some deterministic elements. The authors refer to Goldkuhl and Lyytinen (1982, p. 18) when they emphasize the interactionist nature of organizations, by quoting them as saying “IS are part of the organizational sense-making process, where social situations are interpreted, defined, and evaluated”.

Our model is composed by two stylized types of agents, representing the grouping of the key resources and the interdependent functions needed to develop an innovation into one organizational unit (Van de Ven, 1986). The model is situated in the “modeling middle”, and as such we may call it an “applicable model” in the sense that these expressions were used by Goldberg (2002).

The functions are those of the decision makers, who represent top management, supported or not by Decision Support Systems, simulating a strategy formulation based on the Expected Utility Model, from the Von Neumann and Morgenstern’s (1953) Expected Utility Theory, using the logic that the agents are assumed to maximize their expected utilities during the time set for the model to run; and the knowledge workers, who represent the IS/IT educated collaborators of an organization. Our virtual organization interacts with the external environment through both types of agents, since we interpret the random generation of information needs and recommendations as the changes perceived in the external environment. For instance, knowledge workers may capture information about new technologies in the environment to support the top-decision making process, emulating the process of competitive intelligence or some other specialized forum in which they might participate.

The body of extant literature in the CMOT, based on the contingency approach of the 80’s, being highly cumulative, has shown that there is no one best organizational design, thus changing the focus of the research from locating the best design to locating the relevant tradeoffs specific to a particular situation (Carley, 1995, p. 43), bringing the need of instantiation of a generic model as the one developed by Araújo and Vilela Mendes (2006).

Since we are doing an instantiation of a more abstract model, we firstly describe the model, before eliciting the hypotheses to be tested.

We then test the hypothesis running the algorithm written in Matlab software. The pertinent graphical presentations are revealed as the results of our simulations. A discussion of the results is presented, before we reach the concluding chapter of our thesis. The hypotheses testing supports the basic claim of this study, that the power of the knowledge workers in the decision to adopt an IS/IT innovation within an organization varies with the matching level of ideas between them and the top management, while being dependant of the transactions' depreciation rate, leading to a strong fluctuation of power when the environment is unstable.

Although we use the expression decision makers and focus on the process of decision making, our work is by no means related to decision theory. Our model may be best described as a simulator, as defined by Rouwette, Größler and Venix (2004, p. 352). These authors claim that social simulators are "computer-based simulation games of real-world scenarios" (Rouwette, Größler and Venix, 2004, p. 352) with a necessarily reduced level of detail, and from a systems dynamics perspective. They include:

- a pre-configured formal simulation model, underlying the simulator that establishes how decisions are processed and the outcome is reached;
- a human-computer interaction component, which shows the state of the model and allows the user to manipulate the variables;

- a gamming functionality that sets the simulation parameter like the time period, the rules by which the agents interact or the contextual story where the simulator is embedded.

We used all these features in our model, so we refer to it as a social simulator[9] for studying the adoption of IS/IT innovation. According to Rouwette, Größler and Venix (2004, p. 352) simulation is a particularly valuable tool for research in dynamic decision making in complex environments as is the one we are investigating, which also shows an underlying systems dynamics.

The word simulation is used in Gilbert and Troitzsch's (2005) sense, i.e., a particular type of modelling. The ultimate purpose of using simulation as a modelling tool is to "obtain a better understanding of some features of the social world" (Gilbert and Troitzsch, 2005, p. 4).

[9] For a brief introduction to the use of agent based modelling and simulation of social processes, refer to Srbljinović and Škunca (2003).

Chapter 2 – LITERATURE REVIEW AND STATE OF KNOWLEDGE

2.1 Overview of Innovation Research Literature

Reviewing innovation literature can be seen as an ominous process. In January 2006, the staggering number of 346 million web pages on a Google search for "innovation" was obtained; 25,721 hits were displayed on the Proquest database basic search for the words "innovation(s)" in articles of scholarly journals, with that number lowering to 15,772 when the search was limited to the document title; finally, 12,530 books about innovation were available from amazon.com. These sheer numbers alarm anyone that approaches the subject with such a task in hand, because they show an increasing trend[10] between the year 1955 and 2004, as demonstrated by Fagerberg (2004, p. 2), but, most of all, speak for themselves about the relevance of innovation in human and technical processes nowadays. Moreover, political discourse jumped in and spread the tenet: innovate or die! A typical example of what is being said is the juxtaposition of innovation and economy at the ministerial level in the current Portuguese government, whereas it was aggregated with science and graduated education in the previous governmental arrangement. Fortunately we have authors, like Fagerberg (2004, p. 4), who recognize the impossibility of conducting a fairly good overview of the scholarly work on innovation in current times. Instead of offering a thorough review of the field, Fagerberg (2004) proposes a guide to this rapidly expanding literature. We will limit our review to IS/IT innovation field, not losing sight of the surroundings, but we do not claim this review to be exhaustive.

[10] Compared with the figures from similar searches in November 2005 that were, respectively, 332 million; 24,667; 15,316 and 12,182.

In the advent of a knowledge-based society, innovation is taking strategic importance that goes beyond the development of new products and services, incorporating improvements in business processes and performance (Kodama, 2005). Much more than just another epitomized buzzword[11], innovation starts revealing its nature as we dive into the ocean of scientific literature. This work is obviously limited in time and space and is conducted using a search light to illuminate what we seek as being the relevant scientific work.

As a theoretical problem, innovation is addressed by “such diverse areas of scientific inquiry as economics, management, organizational behavior, sociology, engineering, biology, psychology, history, and political sciences” (Fonseca, 1998). So far, one can say that innovation looks much more like a trans-disciplinary issue than a theme studied only in a particular area of knowledge. Supporting this idea, Fagerberg (2004) recognizes what he calls the “bent towards the cross-disciplinarity” and posits that science is only one among several ingredients in successful innovation. If this operates a plethora of models according to the background of the communities of people who study the phenomena, it also causes “the failure of these communities to communicate more effectively with one another” that lead to lack of progress and a “certain degree of fuzziness with respect to basic concepts” (Fagerberg, 2004).

The relevance of innovation in the political agenda and in the scientific and popular literature is by no means related to a well established meta-theory of innovation. On the contrary, the relevance of innovation on the political or any other policy discourse is rooted on rhetoric (Godin, 2006) rather than science, except for the field of economics. We even have authors like Getz and Robison (2003) criticizing the “innovate or die” mantra, for being naïve because it causes many people to believe in jackpot or lotteries

[11] For a deeper discussion on Knowledge-Based Economy being a conceptual framework or a buzzword, refer to Godin (2006).

solutions when trying to reinvent the whole industry (or, for that matter, a country, we should say) instead of paying special attention to the true sources of long-term high performance. Based on empirical examples, such as the cross-industry study done by Stevens and Burley (1997) who estimated a ratio of 3,000 ideas to only one market succeeded product, and cases of well succeeded firms, these authors state that “the unvarnished truth is that customer-focused processes and basic continuous improvement play a far more important role than innovation in organizational success”, before defending the creation of an internal System for Managing Ideas, since 80% of improvements ideas come from employees and only 20% come through planned improvement activities.

One organization that has seriously taken innovation studies is OECD. This organization has conducted a series of conferences about the subject throughout the years. It has published three editions of the so called “Oslo Manual”, respectively in 1992, 1997 and 2005, which shows clearly that the proper concept of innovation is still in evolution, extending from manufacturing products, to services[12], to models of development and growth of nations. The OECD president of International Workshops on Social Sciences, Luk van Langenhove (2001) distinguishes a certain kind of innovation, different from its economic or technological counterpart, as is the case of social innovation, referring to needs not satisfied by the market (“a new law, organization or procedure that changes the way in which people relate to themselves or to each other, either individually or collectively”) and trying to address the question about who will be the most competitive in the knowledge economy, highlighting the complex relationship that links innovation, society and social science .

[12] For a deeper discussion on innovation in services, see Miles (2004).

Rosenberg (2001), clearly stresses the relationship of Big Science, which produces an intermediate good that “does not ordinarily enter the marketplace, and its economic value should be measured as a possible input to a later project that may eventually lead to a marketable product”. This illustrates the main feature of major innovations, according to Rosenberg (2001), which is the uncertainty in the outcome of the innovation process. The author cites Schumpeter (1928) stating that these uncertainties are “drastically reduced after the first commercial introduction of a new technology, i.e., the successful completion of an innovation resolves all the ex ante uncertainties” (Rosenberg, 2001), opening the door for imitators to diffuse the innovation. In this line, Rosenberg posits that the innovation process cannot be seen on technological grounds alone since major innovations initially are very primitive and so “innovations are, most fundamentally, economic events if they are going to have a large social impact”.

Wolfe (1994) suggests that the underdevelopment of innovation studies relies on the nature of the phenomenon itself, which is a complex and a context-sensitive one. Although innovation (or rather, the creativity that innovation needs) is intrinsic to the human being, and as such as old as mankind, its sustainability, which leads to an innovation-based development in society, is a “recent and unevenly distributed historical phenomenon” (Bruland and Mowery, 2004). The scholarly interest in innovation studies as a separate field is also relatively recent.

Economic historians locate the decade (around 1760) and the place (Britain and Northwestern Europe) where the phenomenon of innovation, as an economy-wide process, involving changes in technology, organizations and institutions, manifested itself for the first time, spanning sectors and groups of products (Bruland and Mowery, 2004). Scholarly interest in the study of innovation is somewhat contemporary of the First Industrial Revolution if we want to mention Adam Smith and its magnum opus, *An*

Inquiry into the Nature and Causes of the Wealth of Nations, first published on the 9th of March, 1776. Recent "important scholarly pieces", e.g. Freeman and Louçã (2002) and Lloyd-Jones and Lewis (1998), on innovations studies, according to Bruland and Mowery (2004), follow the "key innovations" interpretation of the First Industrial Revolution.

Putting aside the industrial R&D that characterized the late 19th Century, we could trace the innovation studies back to 1885, when French sociologist Gabriel Tarde's (2005) first edition of *Les Lois de l'imitation. Etude sociologique* was published, well before the widely accepted father of innovation studies, Joseph Alois Schumpeter first published the *Theorie der wirtschaftlichen Entwicklung* in Leipzig, in 1912, translated later into English by Redvers Opie in 1934, with the title *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle*. Although embedded in Sociology, as is the case of Tarde, or Economics, if we want to mention Schumpeter, Fagerberg (2004, p. 2) claims that innovation studies started to emerge as separate field only in the 1960's.

The aggregation of economy and innovation (with social aims) should not come as a surprise but as consequence of the foundation in 1965 of the Science Policy Research Unit (SPRU), in the University of Sussex, United Kingdom, by Christopher Freeman. SPRU served as a role model to similar centers that spread research on innovation in Europe and in Asia, since mid-1980's. Recently, new research centers and departments have been founded, focusing on the role of innovation in economic and social change (Fagerberg, 2004). Contemporary to the foundation of SPRU, Becker and Whisler (1967) suggested a systemic view of organizational innovation. They advanced a four-stage process that included stimulus, conception, proposal and adoption. The authors also defended that the phenomenon of organizational innovation was related to organizational change or adaptation, although different from these concepts. Particularly inspiring for our model is the following transcription, taken from their article (Becker and Whisler, 1967, p. 467):

"Something internal or external provides a stimulus, an individual conceives a proposal for innovative action, he makes his proposal to fellow members of the organization, and a political process ensues which results in either adoption or rejection of the proposal."

Schumpeterian views of innovation have been dominant in the fields of economics, organizational and management literatures (Fonseca, 1998), where it is correlated with growth in the long term, in accordance with Rosenberg (1982), following the articles by Moses Abramovitz (1956) and Robert Solow (1957). This relation is also present in Scherer (1986) and Tushman and Nelson (1990). Other correlations in this stream concerning the innovational phenomenon include development (Werker and Athreye, 2004); strategic management (Carneiro, 1995); strategic decision-making (Tabak and Barr, 1988); competitiveness (Carneiro, 1995; Braganza, Edwards and Lambert, 1999; Böhringer and Maurer, 2004); strategy (Quinn, 1979; Grover et al., 1997); technology and organizations (Tushman and Nelson, 1990); leadership (Kanter, 1988, 2002; Vera and Crossan, 2005; Isaksen and Tidd, 2006), empowerment (Kanter, 1983; Sundbo, 1996; Paper and Johnson, 1996) and productivity (Leeuwen, 2002), just to name a few. Particularly interesting is the view of innovation as a commodity as referred by Danilov et al. (1997), who characterizes innovation as a subset of new qualities in a whole list of qualities, which "is assumed to be known and partially ordered" (Danilov et al., 1997, p. 195) and Horn (2005), the latter addressing the "changing nature" (or should we say evolution) of innovation. Miller and Morris (1999) addresses it as a "serious problem"

(Miller and Morris, 1999, p. x) that corporate top managers ought to face, distinguishing innovation from R&D, and attributing to both issues the vital role that they play in "the growth, survival, and success of companies and nations" (Miller and Morris 1999, p. ix). The authors, after recognizing that innovation efforts have failed, introduce five strategies[13] to be available for managers, ultimately recognizing that only innovation is able to increase value for customers, thus providing the fundamental competitive need for the firm. They posited in 1999 (Miller and Morris, 1999) that the practice of innovation and R&D was wrong in light of the fact it was based on the 3rd generation model of R&D, supported by a 19th and 20th scarcity-constrained industrial economy model and not in the more abundant, technology-enabled knowledge economy that is supposed to form the basis of the 21st Century. Claims of a move towards a post-capitalist, knowledge-based society have been made before (Drucker, 1993). Miller and Morris (1999) proposed a 4th generation R&D where the critical resources would be ideas, concepts and capabilities that enable "continuous and discontinuous innovation, both of which are mandatory for dealing with the accelerating change that now pervades the marketplace" (Miller and Morris, 1999, p. xii). Managing knowledge, as an intangible asset is completely different from managing tangible assets, for it is people that bring value to it. Rogers (1996) called for a development of a 5th generation R&D, based on five shifts affecting the worldwide marketplace, namely from information to knowledge; from bureaucracies to networks; from training/development to learning; from local/national to transnational; from competitive to collaborative strategy. The author suggested that the asset of this 5th model is knowledge (while technology, project, enterprise and customers were the assets of the previous models) and identified the core strategy as a "collaborative innovation system" and the change factors as

[13] Market share warfare; costs reducing through downsizing, process improvements, quality improvements, and outsourcing; use IT to enhance performance or customer loyalty; acquisitions for growth; exit existing marginal business.

“kaleidoscopic dynamics” (Rogers, 1996). This generational view of R&D was also taken by Rothwell (1992), when a 5th generation model for innovation is called to accommodate the “new electronic toolkit” and a statement is made that “success is people-centered”, since “innovation is essentially a people process”.

Schumpeter, as a distinct and pioneer scientist who first studied innovation related to Economics, also identified a psychological grounds for innovation at individual level, highlighting the central role of the entrepreneur (Fonseca, 1998) (Drucker, 1985) (Quinn, 1979) in the innovational process, especially as the undertaker of the recombination activity of existing resources (Fagerberg, 2004). Fagerberg (2004) refers to that as “a central finding in the innovation literature is that a firm does not innovate in isolation, but depends on extensive interaction with its environment”. In this line of thought we have the views of scholars such as Van de Ven (1986) who posits that “innovation doesn’t exist in a vacuum”, highlighting the socio-cultural mesh that surrounds a particular organization, and constitutes its external environment, and “that institutional innovation is in great measure a reflection of the amount of support an organization can draw from its larger community”.

Lyytinen and Rose (2003) make their point by attributing the atomization of innovation studies, understood as isolated phenomena or several events (like the adoption of Electronic Data Interchange – EDI – or Computer Aided Software Engineering – CASE, instantiations of innovation) to the dominance of pull-side focus in the research outcomes, calling for studies to be conducted on the push-side of the phenomenon. We will come back to this issue later on, when we describe our model.

A different stream associates innovation with organizational change (Weick and Quinn, 1999; Hage, 1999; Edwards, 2000; Greve and Taylor, 2000), organizational learning (Weick, 2002; Bessant, 2003; Harkema, 2003, Lazonick, 2004a; Lazonick, 2004b

Reissner, 2005; Vera and Crossan (2005), creativity (Paper and Johnson, 1996; Huber, 1998; McFadzean, 1998; Borghini, 2005) and culture (Angle, Manz and Van de Ven, 1985; Orlikowski, 1993; Wilson and Stokes, 2005), which are deeply interwoven (Huber, 1998; Reissner, 2005). Other authors, such as Weick (1998) and Vera and Crossan (2005), although relating innovation to other phenomena, they associate it also with improvisation.

A very wide appreciation of the field was followed by the Canadian School of Public Service, the former Canadian Centre for Management Development's. This school conducted the Action-Research Roundtable on the Learning Organization, whose results can be found on a 2000 Working Paper, called *An Initial Exploration of the Literature on Innovation*, being the first approach to the subject introducing what innovation was, based on the range of definitions, the relationship to invention and creativity, innovation and innovativeness, the components of innovation (subject of innovation, new ideas, application, significant change) and broader contextual factors (teams and projects, knowledge ecologies, innovation systems); and what are cited as the major causes of innovation, namely, the stages of innovation, loops of innovation, dynamic models of innovation, innovation inventories, intrinsic factors (risk management strategies, employee empowerment, leadership skills and change management strategies, personal characteristics and capacity or resources) and contextual factors (cultural characteristics, political incentives, organizational structures, infrastructure and policy regime).

Recognizing the contextual dependency of the phenomenon, we must say that we are much interested in innovation and its relationship with mindful (Swanson and Ramiller, 2004) or purposeful (Drucker, 1985) technological change (Rosenberg, 1982), particularly the one related to the IS/IT (Swanson, 1994) and its impact on the success of the pre-adoption process of innovation. This is especially because of its bottleneck dynamics, from which all other phases or stages depend on, and consequently which might have implications in the viability of the organizations in turbulent environments. We focus our attention on what goes on "inside the black box" (Rosenberg, 1982), admitting that a particular economy or ecology is made of many black boxes rather than just one (Kline and Rosenberg, 1986, p. 280). Economists have left the interior of this black box to other scholars of disciplines such as sociology, organizational science, management and business studies (Fagerberg, 2004). Yet following Fagerberg (2004), what goes inside the back box has a lot do with learning, a central topic in cognitive science. This "learning occurs in organized sets (e.g. groups, teams, firms, and networks)" and is "linked to specific context or locations" and time, as shown by historians. These scholars also identified a "technological dimension" of innovation as is the case of Rosenberg (1994). According to Fagerberg (2004, p. 4), "the way innovation is organized, as well as its economics and social effects, depends critically on the specific nature of the technology in question".

As entrepreneurship or creativity and discovery are particulars of the human beings (Miller and Morris, 1999), they are also at the core of the innovation process (Drucker, 1985) (Van de Ven, 1986), despite the fact these phenomena are different in nature, as stated by Wilson and Stokes (2005), we will concentrate now our review in the extant body of literature relevant for IS/IT innovation. This does not mean that we have disregarded other approaches; it is just for the sake of our intent and the scope of this thesis, that we followed Goldberg (2002) and Repenning (2002), who propose simple or applicable models to study some aspect of innovation. The former concentrates on the design of innovation, using competent (those ones that work) genetic algorithms; the latter focus on the implementation stage of the process of innovation and suggests that "the analysis needs to start somewhere" (Repenning, 2002).

Again, the relationship between a particular type of innovation, such as IS/IT innovation, and the economy is still pertinent, following Swanson's (1994, p. 1069) assertion that "there is no return to an age of innocence of information technology within the business", who recognizes the crucial role that IS/IT have in business, specially related to fundamental changes that occur in its environment. Swanson (1994, p. 1070) says,

"For while creative uses originate in many places, it is by means of IS innovation that the new technology is effectively meshed with organization design, process, strategy, and external relationships throughout the enterprise".

Wolfe (1994, p. 406) suggests the following issues that a researcher should address in order to reduce ambiguity in innovation research:

a) "which of the various streams of innovation research is relevant to a research question,
b) the stage(s) of the innovation process upon which a study focuses,
c) the types of organizations included in a study,
d) how a study outcome variable (e.g. adoption, innovation, implementation) is conceptualized, and
e) the attributes of the innovation being investigated."

Later, when we describe our model we will follow Wolfe's prescription, hoping that we can get some cumulative knowledge with our work.

Broad reviews in the innovation research field can be found in Kline and Rosenberg (1986), Van de Ven (1986), Tushman and Nelson (1990), Damanpour (1991), Wolfe (1994), Slappendel (1996); Gopalakrishnan and Damanpour (1997), Damanpour and

Gopalakrishnan (2001), *OECD Proceedings Social Sciences and Innovation* (2001), Milling (2002); Christensen (2002) and Shane and Ulrich (2004).

We have paid careful attention to Fonseca (1998), who offers three impressions of the innovation literature, namely: a “pluralistic mess”, a “social acclamation of (technological) innovation as an end and as a means”, and an “innovation as a cause, as a product or as an emergent property?”.

As a last reference of the broader studies we have surveyed we would like to point out the work of Fagerberg (2004) who, as said above, offers a guide to the literature of innovation, regarded as a systemic phenomenon, “since it results from continuing interaction between different actor and organizations”, in The Oxford Handbook of Innovation. This guide is divided in the following broad headings (Fagerberg, 2004):

- “Innovation in the Making – focuses on the process through which innovations occur and the actors that take part: individuals, firms, organizations, and networks.
- The Systemic Nature of Innovation – outlines the systems perspective on innovation studies and discusses the roles of institutions, organizations, and actors in this process at the national and regional level.
- How Innovation Differs – explores the diversity in the manner in which such systems work over time and across different sectors and industries.
- Innovation and Performance – examines the broader social and economic consequences of innovation and the associated policy issues.”

We have found that most of the innovation studies address in one way or another (i.e., explicitly or implicitly) the following common themes: a definition of innovation; the subject of the innovation and the process of innovation in which we can include the scale(s) of innovation and the spectrum of innovation. As we are interested in a particular subject as is the case of IS/IT innovation and its dynamics we review these items in the following sections, followed by our methodological stance.

2.2. Definitions of Innovation (Ontological Questions)

Before addressing the ontology of the IS/IT innovation as we dealt with it, let us briefly discuss our world view and philosophical standing.

Our world view is based on the critical realism as defended by Dobson (2001). In light of the fact that we are conducting abstract research our interest was directed to the structures and mechanisms that might produce observable events, once empirical studies are conducted. From a philosophical point of view, Klein and Herskovitz (2005) lay ground for theoretical developments in the field of social simulation, addressing computer simulation validation. They defend the testing using computer as a “normal” scientific endeavor anchoring it to Popper’s theory of falsification, by means of the possibility of developing an improved model. Another support for our standpoint comes from Mingers (2004) and his advocacy of critical realism as an underpinning philosophy for information systems, particularly the position of the experimentation, once causal laws must be different from and independent of the patterns of events they generate.

As we might expect with such a longitudinal concept, definitions of innovation abound throughout the literature. Before we continue we would like to refer some related and closely associated concepts (and sometimes taken as synonyms) with innovation, as is the case of invention and improvisation.

Invention differs from innovation according to Fagerberg (2004) as follows: "invention is the first occurrence of an idea for a new product or process, while innovation is the first attempt to carry it out into practice". They are obviously connected although there is a high attrition rate on the side of ideas or considerable time lag between their first occurrence and their successful implementation. Horn (2005) has a similar approach when he declares that "innovation goes beyond mere invention to mean the creative application of technologies, processes or ideas to some useful purpose".

The case of human flight or time travel illustrates our argument, giving an example that one was already implemented and the other that is still in the theoretical lab. Another difference is in the place where they occur. Ideas about inventions can occur anywhere, for example in universities, while innovations occur mostly on firms (Fagerberg, 2004), or other type of need satisfying organization. The transformation of an invention into an innovation requires the convenient combination of "knowledge, capabilities, skills, and resources" (Fagerberg, 2004).

Fagerberg (2004, p. 5) gives an example of the requirements of a firm for turning an invention into innovation: "production knowledge, skills and facilities, market knowledge, a well functioning distribution system, sufficient financial resources and so on", highlighting the combination requirements, or quantity of "right stuff"[14] that is needed.

The other concept often taken as innovation is improvisation. Both processes tend to go against order and control. These last processes have a particular emphasis in the organizational theory. Weick (1998) develops the concept of organizational

[14] Defined by the "greater innovation-related needs and abilities", in the words of Jeyaraj, Rottman and Lacity (2006, p. 2).

improvisation from the jazz performance metaphor and etymological sense of the word. The first accounts for the extemporal breaching of order and control while at the same time a new order is created in real time. The etym *proviso* means providing something ahead of time, thus implying premeditation. When the prefix *im* is added, then a negation of the etym is reached, meaning that improvisation deals with the "unforeseen", "without a prior stipulation", "with the unexpected" (Weick, 1998, p.544). The author identifies several grades in the improvisation process, namely interpretation, embellishment, and variation, ending in improvisation, mirroring the spectrum the change process in organizations from incremental to transformational change. Weick (1998, p. 546) states that improvisation shares the same type of phenomenon studied by the "chaos theory", but does not state the meanings or definitions of improvisation and innovation. He tries to portray organizational improvisation as a substitute to organizational innovation, evident in his claim: "the normally useful concepts of routine and innovation have been stretched informally to include improvisation". Ultimately he recognizes some limitations on the use of the jazz metaphor (Weick, 1998, p. 552) acknowledging that "musicians love surprises but managers hate them". We should add that this is absolutely true for managers especially when facing unpleasant or bad surprises. Although work is being done in order to integrate improvisation in management theory, in our view the grounds that support this stream are not solid enough for to draw any line of investigation. Vera and Crossan (2005) get rid of the cultural background and specific musical skills implied by the jazz metaphor and focus their study on theater improvisation. Their idea is to use the benefits of "accessibility", "transferability" and "universality" of theater improvisation on the basis that it relates more closely to the organizational day to day. Improvisation in theater involves "speech, gestures and facial expressions, which are all materials of everyday interaction" (Vera and Crossan, 2005, p. 204). They cite Miner et al. (2001) in the differentiation of improvisation from creativity and innovation arguing that "creativity may involve absolutely no improvisation" and "innovation may be created through improvisation, but also through planning". The authors conclude that it is the "spontaneity and real time nature that differentiates creativity and innovation from improvisation". Orlikowski (1996) exploit a case study, using groupware to study improvisation in an organizational transformation setting but thus far we couldn't find any other developments related to her approach.

Albeit we have discarded improvisation in our definition of innovation, a related concept such as creativity has to be included in our discussion. Quinn (1979) says that innovation is the creation and introduction of original solutions for new or already identified needs. Here we should differentiate between creativity, which is seen as "the generation of new ideas (…), essentially an individual act" and innovation defined as "the successful exploitation of new ideas (…), fundamentally a social process built on collective knowledge and cooperative effort" (Wilson and Stokes, 2005). Wilson and Stokes (2005), analyzing the cultural field, posit that "for the entrepreneur to innovate, he or she must collaborate with others, such as venture capitalists, lawyers, and industry professionals, in order to leverage resources". They also affirm that "in essence, managing creativity and managing innovation require different levels of collective activity carried out between different agents", associating creativity with "intrinsic motivation".

Paper and Johnson (1996) introduce a theoretical model linking empowerment, creativity and organizational memory. They show that empowered workers generate creative solutions to problems. These solutions can only be useful if they are recorded into organizational memory. Organizations that empower the workforce have better outcomes when compared with those that do not.

Rosenfeld and Servo (1991) distinguish creativity from innovation, stating that creativity deals with the production of new ideas and innovation makes money out of them.

"Innovation = Conception + Invention + Exploitation"

Conception is defined as an idea that is novel with respect to a frame of reference (individual, departmental, organizational, or all accumulated knowledge); invention is the transformation of that idea into reality; and exploitation refers to getting the most out of the Invention.

Creativity is the result of "a large number of associations in the mind followed, by associations followed by the selection of associations that may be particularly interesting and useful", in the words of Amabile et al. (2002). These authors, after developing a matrix that highlight the relationship between "likelihood of creative thinking" and "time pressure", stress that peoples' attention might be drawn to many things simultaneously, and that people interact a lot more with groups of persons instead of one-to-one relations.

Thus, systems or at least network[15] (somewhat less ambitious) perspectives are now common in the innovation literature.

Schumpeter is quoted to have been the father of innovation studies in economics and in social change, which is not actually true if we take into consideration the stated work of Gabriel Tarde as Jon Sundbo (1999). Using a broad approach to the concept, he first defined innovation as "the entrepreneurial function" of "new combination" of existing resources. Later, he recognized the role of large firms in the innovation process,

[15] For a review on networks and innovation, refer to Powell and Grodal (2004).

especially in the diffusion stage, originating clusters (in certain industries and in certain time periods), business cycles and long waves in the world economy (Fagerberg, 2004). According to a review by Jim Love (2001), Jon Sundbo (1999), in a book called *The Theory of Innovation*, defines innovation as the "first business use of something new which results in commercial gain, and includes product, process and organizational innovation as well as a new type of marketing or overall behavior on the market, including a different relationship with the state and other official regulation systems, societal organizations or specific consumers".

Generally speaking, all definitions of innovation are related to these first views, which included five different types of innovation: new products, new methods of production, new sources of supply, the exploitation of new markets and new ways to organize business (Szmytkowski, 2005).

For Langenhove (2001), innovations are new ideas or practices that transform the policy and practice of local developments. Reissner (2005) associates new ideas with a prerequisite and a trigger for the organizational learning needed to accommodate change.

Szmytkowski (2005) in a study draft that originated insights[16] for the European Commission developed a framework to analyze the definition of innovation according to the following factors: object of the definition, process showed in the definition, subject of the definition, results or outputs, and timeframe of the defined process. According to this author,

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[16] More exactly, for the European Commission DG INFSO Unit C03. Another Study Draft with the title *Innovation Conceptualisation and Innovation New Models Theoretical Summary* is available in the web address http://www.interecho.com/~smith/daniel/resources/paper_innovation_v2.pdf as of October, 21st, 2006; another paper from the same author, with the title *Innovation analysis – Innovation Definition Criteria Oriented Assessment of the FP6-IST Projects - Analysis of the FP6-2002-IST-1 Projects* could be found at http://www.interecho.com/~smith/daniel/resources/FP6-IST_INNOVATION.pdf as of 21 October, 2006.

> "the purpose of defining innovation is to set a clear set of tools as a way for capturing it as an economic phenomenon, what could lead eventually to socio-economic impact assessment analysis (at the micro and macro economic level). The measurement toolset can be applied to the (classical) linear innovation process (R&D, patent creation analysis), but more importantly network models, manifested by spillovers and inter-sector knowledge exchange. The task for measuring innovation is [a] very complex and fragile problem".

After addressing several definitions of innovation, Szmytkowski (2005) recognizes that some of the definitions overlap each other, although some of them have a narrow scope. Another problem is the use of the word "technological", which could have unclear meanings. A general conclusion, states the author, "can be drawn that the definition framework concentrate on the economic (market) aspect of innovation". Even though the definition is not result oriented (does not state the necessity of the innovation economic impact) it ultimately seeks it.

Kline and Rosenberg (1986, p. 283) posit that "it is a serious mistake to treat innovation as if it were a well defined, homogeneous thing that could be identified as entering the economy at a precise date – or becoming available at a precise point in time…The fact is that most innovations go through drastic changes in their lifetimes – changes that may, and often do, totally transform their economic significance. The subsequent improvements in an invention after its first introduction may be vastly more important, economically, than the initial availability of the invention in its original form".

Based on Hage (1999), Hakerma (2003) proposes that "the most widely definition of innovation is that it is the adoption of an idea or behavior that it is new to the organization". She gives examples such as a new product, service or technology and relates this novelty to change in the organizational context[17]. For the purpose of her investigation, Hakerma (2003, p. 341) adopts the definition of innovation as a "mentality that express itself through learning", or a "knowledge process aimed at creating new knowledge and geared towards the development of commercial and viable solutions". As a process, innovation is defined by the author "wherein knowledge is acquired, shared and assimilated with the aim to create new knowledge". The author's view is that people are the "owners of knowledge", the "drivers of innovation" and following Coleman (1999), "products and services are merely regarded as the embodiment of knowledge".

The Canadian School of Public Service, the former Canadian Centre for Management Development, uses a working definition ("an attempt at a synthesis of the literature and contains a series of components that must exist for innovation to exist"): "innovation is the creative generation and application of new ideas that achieve a significant improvement in a product, service, activity, initiative, structure problem or policy" (*An Initial Exploration of the Literature on Innovation*, 2000).

Nonaka (1994) was one of the first scholars to theorize about the relationship between knowledge and innovation, employing the widely accepted idea that new knowledge comes from the conversion of tacit knowledge into explicit knowledge.

For Van de Ven et al. (1999, p. 16), innovation is seen as being the "nonlinear cycle of divergent and convergent activities that may repeat over time and at a different organizational levels if resources are obtained to renew the cycle"; Lyytinen and Rose (2003) state that "a general and widely accepted definition of innovation is that it involves", according to Daft (1978, p. 197), an "adoption of an idea or behavior that is new to the organization adopting it".

[17] For a thorough review of Organizational Innovation refer to Lam (2004).

Becker and Whisler (1967, p. 463) suggested the definition of innovation "as the first or early use of an idea by one of a set of organizations with similar goals".

Sometimes it is easier to point out what a particular concept is not, than what it exactly is. This might be the case of innovation. Some authors have the tendency to approach innovation as if it was applied science. Kline and Rosenberg (1986) used the "linear model" to express the common misconception of what is not innovation. Several other models that refer to "stages of innovation" offer a similar view of the innovation process, beginning with research (science), then development, production and marketing but only serve the interest of researchers and scientists and the organization in which they work (Fagerberg, 2004).

After all, one can say that a notion that pervades these definitions is the novelty of the process(es), although newness by it self is not considered innovation. Newness[18] has been proposed as the "common denominator" and a "meaningful measure of innovation", by Johannessen et al. (2001). These authors cite Slappendel (1996) on her recommendation that the perception of newness serves to distinguish innovation from pure change. They develop their claim stating that obtaining answers to the questions "what is new", "how new", and "new to whom", one can have a single construct at the organizational level to measure innovation. As such, the construct should be context independent, confirming earlier allegations by Van de Ven (1986), Damanpour (1991), and Nohria and Gulati (1996) that a typology of innovation would fragment [the concept of] innovation (Johannessen et al., 2001). Using a systems language we would say that innovation displays the unregulated or unexpected feedback loops (Repenning, 2002; Buijs, 2003; Schwaninger, 2004). Independently of the context, the process of

[18] Newness, by itself, is not an economic advantage (Kline and Rosenberg, 1986).

innovation mostly starts with an idea (Hakerma, 2003), being pushed further by another development as is the case of R&D.

Lane and Maxfield (2005) elaborate around the relationship between ontological uncertainty and innovation, since “innovation begins with a new attribution of functionality – an idea for a kind of activity in which people may wish to engage that can be realized by means of an artifact”, and as such some of them may be unanticipated.

Fuglsang and Sundbo (2005) suggest the idea of innovation as a social system within an organization, at the same level of other systems such as the production system or the profit maximizing system.

An ABM was employed by Cartier (2004) to simulate the emergence of a dominant innovation and a reduction of diversity with selection processes. Cartier’s (2004) model although evolutionist reproduces Darwinian Lamarckian[19] adaptation mechanism based on project management knowledge.

For the purpose of our model, innovation is twofold. Firstly, it happens in the random generation of the characteristics of the agents, which by the very simple nature of the randomness means novelty for the system. Subsequently, under the situations described in Chapter 1 above, a search happens, followed by a matching mechanism. Selection comes next. Then, innovation is provoked, by the substitution of the agent with the poorest performance, by another with the worst characteristic flipped so it can adapt to the needs of the decision makers. With this model, which is described bellow, we focus on organizational level organization and we guarantee that an evolutionary mechanism can be studied. One can say that our model is an evolutionary model, within the ecological stream (Fuglsang and Sundbo, 2005), because we suppose a symbiotic

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[19] Following Cartier (2004), “experimentations are Lamarckian processes of transformation (technologies go along uncertain paths through minor changes and trial and error processes”; “exchanges are Darwinian processes of selection (development of new products means recombination of existing knowledge”.

relationship between top management and knowledge workers, as defined bellow, and not the survival of the fittest as in a common Darwinian evolutionary model. Implied in these models is the notion that the agents may survive even though they don't perform in the most effective way, given that "the criteria for effectiveness is complex and related to many activities" (Fuglsang and Sundbo, 2005, p. 331). Typically, mutations are allowed for some type of agents and new rules of survival are introduced.

2.3. IS/IT innovation

As it has been said, our work will focus on a particular type of innovation: the IS/IT innovation at the organizational level.

First, within the scope of this thesis, we will refer indistinctively to either IS, IT or IS function (ISF) (Kettinger and Lee (2002), as a novelty to the top management and or to the professionals that are connected by means of some working relationship through organizational ties that is somehow related to the particulars of those subjects. The reason for this approach is that certain fundamental features in the innovations may include both new information technology and or new manners of organizing human work within one organization, not on an easily calculated proportion (Swason, 1994) and so intricate that a distinction becomes superfluous.

Then, within the algorithm of the simulation, we will use the construct "IS/IT Related Innovation"[20] to designate the novelty brought by "peers or other members from an individual's social network" (Jeyaraj, Rottman and Lacity, 2006, p. 13) into the matching of needs of counselling from top managers by knowledge workers as defined in Chapter 3 below.

[20] This construct is an adaptation of the "IT-Related Organizational Innovation" expression used by Fichman (2001).

In 1994, Swason (1994, p. 1073) identified 22 previous studies of IS innovation, spanning the period between 1977 and 1992. Attributing the responsibility of inducing the IS innovation to the "IS unit", the author affirms that, "historically, innovation has been the very business of IS in organizations, even though it has not always been recognized as such, since IS inception as a functional unit in the 1950's". Swason (1994) develops new theory and posits three basic types of IS innovation, namely: Type I innovations, those confined to the IS task; Type II: those that support the business administration; and Type III, those that are imbedded in the core technology of the business. Type I is further subdivided into two subtypes, according to the focus of the innovation, Ia, for innovations that have the focus on the IS administration and Ib, for innovations that have their focus on the technical IS task. Type III innovations are also subdivided into three subtypes: IIIa, centered on the business's core work process; IIIb, includes basic business products and services; and IIIc, supports the integration with suppliers, distributors or customers. This model addresses the pervasiveness of IS/IT and the classification is in accordance with business impact. Swanson's tri-core representation became known as the tri-core model. This typology has gained empirical evidence as demonstrated by Grover et al. (1997) and is extensively used in IS/IT innovation studies (e.g., Lyytinen and Rose, 2003). They have also an adopter oriented view, since there may be significant lags since the emergence of the enabling technologies and the actual decision to adopt it.

Swanson (1994, p. 1072) defines IS innovation as a specialization of the broad definition of innovation. According to the author this specific type of innovation is an "innovation in the application of digital and communications technologies (now commonly known as information technology, IT)".

From the overload of definitions of innovation, an incommensurable number of definitions is also available for IS/IT innovation in the literature. For instance, Swanson and Rammiller (2004) define the phenomenon of IS/IT innovation in terms of organizational process, in line with our declared intention. This view is also shared by Fichman (2000) and Gallivan (2001), according to Swanson and Rammiller (2004). Their aim is to study the IT applications new to an organization, or how IT is applied in novel ways in the organization, having the typology of Swanson (1994) as a backbone.

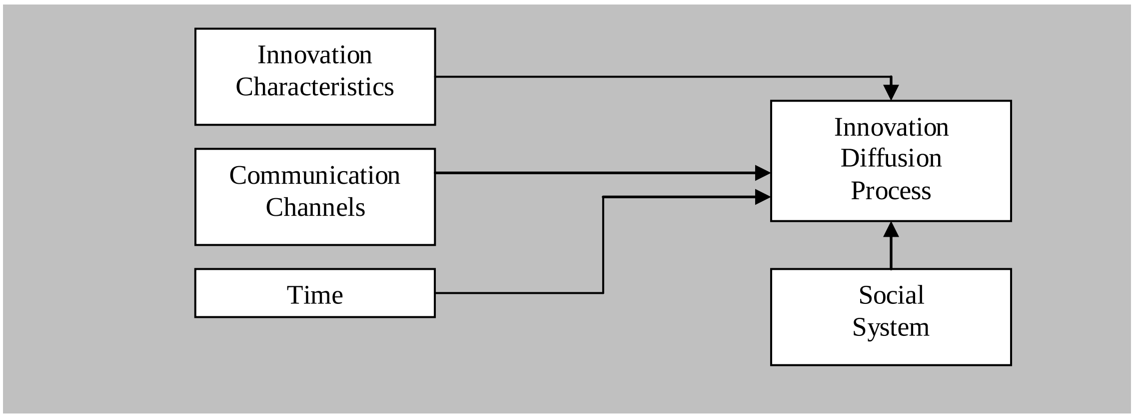
Kettinger and Lee (2002, p. 79) distinguish between IT as the enabling tools "providing automated storage processing, and communication of information, including computer and network hardware and software", while IS is defined as a "set of production and services activities, including people, procedures, and technology to collect, process, store, and distribute information to solve specific organizational problems or to support specific business decisions". The authors refer to an ISF as an interchangeably expression referring either to the IS department or IS group, "to represent the organizational unit responsible for IS service delivery".

From the definition of IS/IT innovation by Swason (1994, p. 1072), the distinction done by Kettinger and Lee (2002, p. 79) and the pervasive nature of the phenomena described by Lyytinen and Rose (2003), which "involves both a technological component (hardware and software) and an organizational dimension captured by such features as new forms of work, business processes or organization methods" we have found the basis for a broad view of IS/IT innovation. Thus, our working definition of IS/IT innovation involves any novelty in IS, IT, personal skills, processes and practices involving information and communication technologies (ICT) in an organizational setting.

Swason's tri-core model was developed having in mind the "business impact" that IS/IT might have. "Products" were obtained in the environment for "conversion". A "value-adding process" would "provide" transformed "products" to the market (Swason, 1994, p. 1076).

Another review of IT innovations is brought by Prescott and Conger (1995), who have a classification based on IT "locus of impact" and "research approach", based on the diffusion of innovations (DOI) research. They review "70 IT related DOI research studies" published between 1984 and 1995. DOI research has its roots on the studies of Ryan and Gross (1943) and investigates the "evaluation, adoption and implementations of innovations" (Prescott and Conger, 1995). DOI research includes the work of Rogers (1983), who defines diffusion as "the process by which an innovation is communicated through certain channels over time among the member of a social system" Rogers (1983, p. 5). To illustrate this process (Prescott and Conger, 1995, p. 21) adapt the model developed by Rogers (1983) as illustrated in Figure 1.

Figure 1 – The Innovation Diffusion Process Model



Source: Prescott and Conger (1995, p. 21)

Still following Rogers (1983), diffusion is thus considered broadly to include stages that at simplest formulation include adoption and implementation. Adoption, which may be mandatory or voluntary, includes three sub-stages designated as "knowledge acquisition", "persuasion and learning" and "decision" (Prescott and Conger, 1995, p. 21). Prescott and Conger (1995, p. 23) admit that they have tried to apply Swason's model but they have found difficulties in discerning the administrative from the technical cores, especially in services, where they are "closely coupled, and with reengineering are melding together". After some reflection they have adapted Swason's typology into four classes, according to its locus: internal to the IS unit, intra-organizational, inter-organizational, an unspecified. According to the research approach, the authors have found three typologies of studies: those that are focused on factor research (also called "variance research"), that try to found variables dependent on the level of analysis (individual or organizational); stage research, as research based on the process, alternative to factor research, that include either longitudinal studies or the identification of relevant variables along the IT process or multiple stages; and other research, not clearly classifiable.

Prescott and Conger (1995, p. 36) conclude that their approach is useful to classify DOI research. They suggest that a "forceful IS unit" doesn't need so much organizational support, raising the issue who, at the organizational level, determines the adoption of IT innovation. The authors recommend that further research should be developed in order to analyze the two basic levels of adoption decision: managerial level and individual level.

The "innovative firm" of Lazonick (2004b, p. 51), is a "social organization", because "the reallocation of its resources is a social process in which different group of people can have very different interests".

Fichman (2004a) advances the idea that IT innovation research has been under what the author calls the "dominant paradigm". This paradigm asserts that innovation is explained by economic-rationalistic models, which follow a simple relation between the “right stuff” (i.e., “greater innovation needs and abilities”) and the “quantity of innovation” (i.e., “frequency, earliness, or extent of adoption”). Using a different terminology, later in the paper (Fichman, 2004a, p. 317) he calls “independent variables” to the “right stuff” and “dependent variables” to the “quantity of innovation”. This relationship favors the development of a pro-innovation bias, which states that more right stuff brings more inherently good innovation, which is not exactly true. Fichman (2004a) challenges the researchers to explore issues outside of the dominant paradigm and develops seven perspectives, namely: “innovation configurations”, “social contagion”, “management fashion”, “mindfulness”, “technology destiny”, “quality of innovation”, and “performance impacts”, each of these connected with the key citations. Then they are related to a “central concept”, “a central argument”, and with “key research questions”. For instance, of particular interest for our thesis is the perspective of “innovation configurations”, based on Ragin (1987, 1999). The central concept is that “an innovation configuration is a specific combination of factors that are collectively sufficient to produce a particular innovation-related outcome”; the central argument is that “the factors that affect complex phenomena (such as large scale IT innovation) can interact in complex ways that go beyond simple linear interaction effects, and thus must be viewed holistically to draw valid conclusions”; the associated key research question is

“Which holistic combination of factors explain IT innovation outcomes, especially in cases where there are smaller numbers of large scale events with more extreme outcomes (i.e., dramatic success or failure)?”

We have seen before that a central topic in IS/IT innovation is the decision making process that leads to the adoption and diffusion of these particular innovations. This has been described by “the process-driven architecture model”, developed to bridge the “business-IT divide”. This model includes four layers, namely technology integration, services, information and processes (Strnadl, 2006). When situated at the individual level one might consider the IS/IT professional, the user, or the manager. Examples of such innovations include e-mail systems, the World Wide Web, microcomputers, spreadsheets, and operating systems (Jeyaraj, Rottman and Lacity, 2006, p. 3). On the upper level of analysis, say a collective of individuals, either aggregated around IS units or entire organizations, we have scholar studies of such innovations as electronic data interchange, telecommunications technologies, data base management systems, smart-card payment systems, and computer-aided software engineering tools (Jeyaraj, Rottman and Lacity, 2006, p. 3). Several theories have been proposed for explanation of either level of analysis, although only one – Innovation Diffusion Theory by Rogers (1983) – was found applicable to both levels. Although situating our study at the process layer, this is seen as an emergent property of the interaction of individuals. We use a table from Jeyaraj, Rottman and Lacity (2006, p. 3) that summarizes those theories.

These authors review the predictors, linkages, and biases in IT innovation adoption research. They selected 48 empirical studies on individual and 51 studies on organizational IT adoption that were published between 1992 and 2003. Using the “dominant paradigm” from Fichman (2004a) they have identified 135 independent variables, eight dependent variables, and 505 relationships between them. The sample included qualitative as well as quantitative studies. They have used a particular type of coding scheme instead of a meta-analysis, thus being able to reveal the existence of a significant relationship and not its strength as permitted by meta-analysis.

Table 1 – Theories Used in Individual and Organizational IT Adoption Research

Theory	Main Autor(s)	Used in Individual Adoptions Studies	Used in Organizational Adoptions Studies
Innovation Diffusion Theory	Rogers (1983, 1995)	X	X
Perceived Characteristics of Innovations	Moore and Benbasat (1991)	X	
Social Cognitive Theory	Bandura (1986)	X	
Technology Acceptance Model	Davis (1989)	X	
Technology Acceptance Model II	Venkatesh et al. (2003)	X	
Theory of Planned Behavior	Ajzen (1991)	X	
Theory of Reasoned Action	Fishbein and Ajzen (1975)	X	
Unified Theory of Acceptance and Use of Technology	Venkatesh et al. (2003)	X	
Diffusion/Implementation Model	Kwon and Zmud (1987)		X
Tri-Core Model	Swanson (1994)		X

Source: Jeyaraj, Rottman and Lacity (2006, p. 3)

Jeyaraj, Rottman and Lacity (2006) used and defined the following dependent variables: “perceived system use”, “intention to use”, “adoption”, “diffusion”, “rate of adoption”, “outcomes”, “actual system use” and “time of adoption”. The definitions particularly important for our study are:

- “Adoption – whether a person or an organization is an adopter or a non-adopter of an innovation (usually measured as a binary variable based on self-assessment)”;
- “Rate of adoption – the diffusion curve over time (usually the percentage of adopters in a population);
- “Outcomes – the success of the innovation (typically measured as perceived satisfaction of benefits);
- “Time of adoption – a person’s or organization time of adoption”.

Then they indicated their findings about what were the best predictors of IT adoption by individuals, which are: top management support, computer experience, perceived usefulness, behavioral intention and user support. Regarding organizational level, the best predictors are: top management support, external pressure, and organization size. Appreciating the linkages Jeyaraj, Rottman and Lacity (2006), have found that the linkages between individual and organizational IT adoption at the level of the independent variables were very weak. Top management support was the only good predictor for both types of adoption studied. At the aggregated level, they have suggested two collections of independent variables for the prediction of IT innovations by both individuals and organizations, namely innovation characteristics and organizational characteristics. The biases identified were the pro-innovation bias (all adoption is good), rational bias (adopters make rational decisions), recall bias (methodological based biases, e.g., self reports are unreliable), and adopter bias (nonadopters are understudied). Finally, the authors developed ten prescriptions (four for the predictors, three for the linkages and three for the biases). Of particular interest four our study are three prescriptions that we intend to use. Two are related to linkages[21]:

> 6 – "use environmental characteristics in individual adoption research".
>
> 7 – "increase the study of rate of adoption as a dependent variable in individual adoption research".

And one is related to the biases:

> 8 – "increase the study of "outcomes" as a dependent variable in both individual and organizational adoption research to overcome the pro-innovation bias".

[21] The numbers are those of the original paper.

These selection of prescriptions is related to the type of variables we are able to simulate (e.g., external pressure and influence, either peer or coercive simulated by random bits) and the Jeyaraj, Rottman and Lacity (2006, p. 13) assertions that among the 252 relationships examined within the individual context, none inspected the rate of adoption or included environmental variables; and "little is known about the time or rate at which individuals *within*[22] a system adopt different IT innovations, despite the general understating about the S-shaped diffusion curve".

Fichman (2001, p. 450) argues for increased attention to "aggregated measures in the study of organizational innovation with IT". We are endorsing this challenge, since we employ an aggregate measure (the growth rate of Power to influence decision making about IS/IT innovations) as synonym of innovation efficiency.

2.4. The Processes of Innovation

Effective innovation needs a complex set of different ideas and solutions. This includes a transformational process in such a way that technological and economic considerations are intertwined, that make processes and systems complex and variable (Kline and Rosenberg, 1986). The interactions among people in the social system are, therefore, at the core of any type of sequence or iteration. Bargaining of ideas should be seen as the first step into any type of innovational process.

Sundbo (1996) states that there are two alternatives for firms to engage into organizing innovation activities: the expert system (R&D departments) and the empowerment system. This last system is the equivalent of corporate entrepreneurship[23] and is connected to low-tech and service firms. Taking a resource based theory approach he

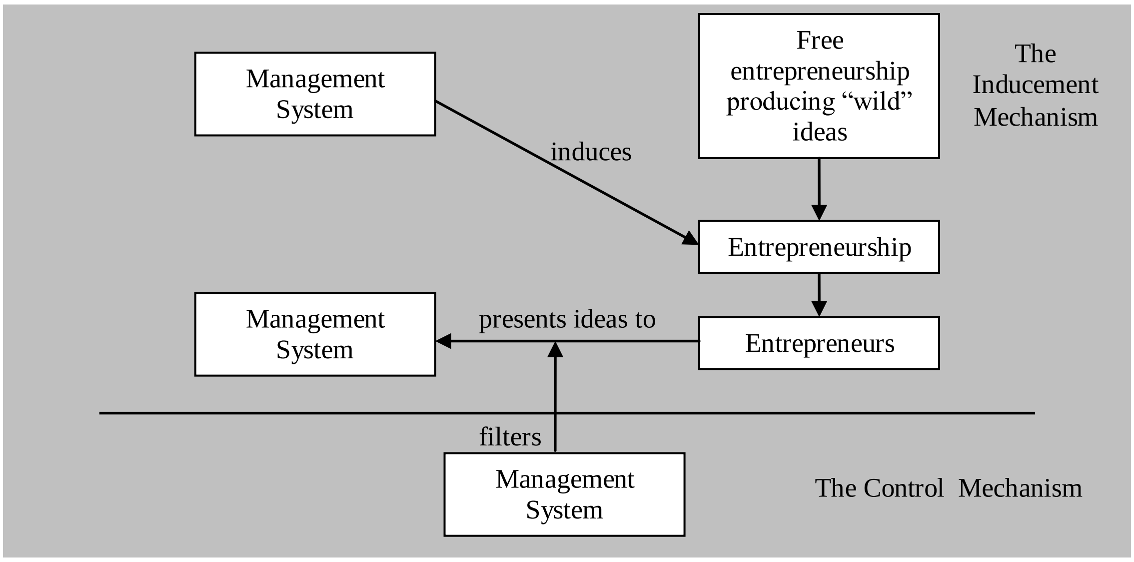
[22] Italicized in the original.

[23] Corporate entrepreneurship is also referred as intrapreneurship by Pinchot (1985) and Mintzberg (1989).

posits that empowerment should be controlled. Otherwise, the uncontrolled empowerment, *per se*, would consume too many resources. Taking a linear approach, empirical evidence was gathered following the stages of idea generation, development and implementation, which showed that Danish firms were stimulating and balancing the empowerment. The balancing is described as a "dual organization structure: a loosely coupled interaction structure, which is an informal structure in which entrepreneurs thrives, and a management structure, which induces and controls free entrepreneurship". Basically, the free entrepreneurship produces "wild" ideas and stimulates entrepreneurship; management system induces entrepreneurship; entrepreneurs introduce ideas to management system, which filters those ideas. The inducement system uses the following mechanisms: openness and networking; empowerment of customers; strategy; corporate culture; rewards; innovation department; top-entrepreneur; practical instruments. The control system uses the following mechanisms: economic and time-use control; strategy; innovation process and decision path; innovation department, top-entrepreneur; organizational learning (Sundbo, 1996, p.407). We will call this balance between the inducement system and the control system the matching level in the model described in Chapter 3. For an ideographic representation of our model we reproduce the schematic view from Sundbo (1996, p. 407) as our Figure 2.

Kline and Rosenberg (1986, p. 75), consider the process of innovation as an "exercise in the management and reduction of uncertainty". Therefore, organizing this exercise in comprehensive ways that might be useful for a community of stakeholders has been the activity of several scholars.

Figure 2 – Model of Balancing Innovation Empowerment



Source: Sundbo (1996, p.407)

Quite a few "interactive innovation frameworks" are identified by Manley (2003). We use her summary, which we organized chronologically, of those models as our Table 2[24] just for exemplification purposes.

Table 2 – Interactive Innovation Frameworks

Theory	Main Autor(s)
Technology Regimes	Nelson and Winter (1982)
Development Blocks	Dahmén (1988)
Industrial Filieres	Van Tulder and Junne (1988)
Complexes	Glatz and van Tulder (1989)
Clusters	Porter (1990)
Innovation Districts	Pike, Becanatti, and Sengenberger (1990)
Innovation Milieu	Camagni (1991); Ratti, Bramanti, and Gordon (1997)
Business Networks	Bureau of Industry Economics (BIE), Australia (1991)
Innovation Networks	De Bresson and Amesse (1991)
Technological Innovation Systems	Carlsson and Stankiewicz (1991)
National Innovation Systems	Lundvall (1992); Nelson (1993)
Regional Innovation Systems	Cooke, Uranga, and Etxebarria (1997)
Competence Blocks	Eliasson (1997)
Value Chains	Walters and Lancaster (2000)
Complex Products and Systems	Hobday, Rush, and Tidd (2000
Sectoral Innovation Systems	Breschi and Malerba (2000)

Source: Manley (2003)

[24] This is not to be seen as an exhaustive review of the "approaches" (Edquist, 2004, p. 486), instead of "theories" about systems of innovation. The references are those of Manley (2003) and not necessarily the first time that the "approach" was advanced in the literature. The table intends to be an example of the diversity of "approaches" taken by authors.

In the context of our thesis, we assume that the innovation process is a dynamical (Milling, 2002) (Lyytinen and Rose, 2003) one, meaning that success and failure are the outcomes of the interaction among many agents deeply intertwined and often deeply uncertain. The word "process" is used in the sense of a certain sequence of activities or endeavours, not necessarily continuous but cogently iterative, as suggested by Lazonick (2004b, p. 51) and irreversible during the run of a particular simulation for a specific set of inputs. For such a process to be revealed in the innovation studies, a system is presumed to exist either explicitly or implicitly. For a deeper discussion on innovation processes, refer to Pavitt (2004). This author, among other considerations, refers the highly "contingent nature of innovation" and that "innovation is (…) essentially a matching process"[25].

We base our approach to the definition of process of innovation on Van de Ven (1986, p. 591). According to this author, the process of innovation is "the development and implementation of new ideas by people who over time engage in transactions with others within an institutional context". Although we discard the implementation phase in our work, we find the transaction of ideas in the institutional context very inspirational for research purposes.

We also take the stance that our virtual organization is already a complex adaptive system (CAS) (Gell-Man, 1995; Dooley and Van de Ven, 1999, p. 359) to guide our study, embedded in another CAS, as is the case of a specific social system. According to Carlisle and McMillan (2006, p. 4), "a CAS does not 'differentiate' between long term and the short term – it simply self-organizes appropriately", which makes them especially appealing for studying interactive process, where a decision has to be made at

[25] The matching is justified for it involves "the exploration and exploitation of opportunities for a new or improved products, processes or services, based either on an advance in technical practice (…), or a change in market demand, or a combination of the two. Pavitt (2004) recommends a paper by Mowery and Rosenberg (1979) as a classical one on this issue.

each time period and then see the outcomes over the long run. We have the support of Wolfe (1994) who cites some previous work to say that the innovation process is "complex, nonlinear, tumultuous and opportunistic", Van de Ven (1986) who purposes a biological metaphor for "the innovation process is viewed as consisting of iterations of inseparable and simultaneous-coupled stages (or functions) linked by a major ongoing transaction process", and Rosenfeld and Servo (1991) who simply state that "the innovation process is complex".

Fagerberg (2004) points out that "one of the striking facts about innovation is its variability over time and space", relating this phenomena to earlier Schumpeterian views of clustering in certain sectors, areas and time periods.

As stated by Lewin (1999), on a special issue of the *Organization Science* periodical dedicated to address "the implications of complexity research for organization studies in the context of new ways of modeling dynamic, nonlinear complex systems for advancing theoretical and empirical research in organization studies (e.g., theorizing within co-evolutionary frameworks, decomposition of nested phenomena, multidirectional causalities)", the new management perspective "requires internal processes as self-generated sources of dissipative energy, such as improvisation, product champions and emergent strategies". Focusing on such a co-evolutionary framework to study innovation phenomena, we can follow a similar approach to draw arbitrary and naturally porous frontiers to divide the sub-fields that deal with innovation, always having in mind that innovation and technology are objectively social phenomena. We will contextualize this issue when we mention the methodology of our study.

We must accept that what is true about the problems surrounding large-scale complex systems, namely the designing, managing and coordinating the myriad of activities that compose such systems (Ethiraj and Levinthal, 2004) is also true for the activities that guide to innovation.

Drucker (1985) considers innovation as a conceptual and perceptual activity. He affirms: “would-be innovators must also go out and look, ask and listen”. Therefore, the connection between the entrepreneur and his or her context has a profound cognitive background. It’s a matter of sensing, interpreting, creating and using knowledge, activities only related to human endeavors (Miller and Morris, 1999, p. xii).

Utterback (1971) uses a model to replicate the process of technical innovation within a firm. The model develops over time and has three sub-processes, namely, idea generation, problem solving, and implementation and diffusion. We are addressing the first, “the idea generation phase results in origination of a design concept or technical proposal, perhaps via synthesis of several pieces of existing information” (Utterback, 1971, p. 78). Sequentially is subdivided into the recognition of a need, recognition of a technical means to meet the need, and synthesis of this information to create an idea or proposal for development.

Rather than episodic “invention and innovation are a continuous process” for “what we think of as a single innovation is often the result of a lengthy process involving many interrelated innovations” (Fagerberg, 2004).

Specifically related to the IS/IT field, Kettinger and Lee (2002) posit that “to a large extent, deciding who actually drives IT adoption depends on the power and influence users and the ISF has over IT planning and resource allocation”. Within this field, personal innovativeness was used by Agarwal and Prasad (1998) as a construct, with psychometric properties, in order to moderate de effects on the antecedents and consequences of individual perceptions about a new IT.

We are aware that “innovation can happen everywhere” (Castellaci et al., 2004, p. 15), thus indicating that low-tech, established or traditional companies are becoming more dependent on the new technologies produced by high-tech industries, demonstrating that the diffusion of innovation is not neutral. This may be important at the meso scale as we progress towards the network society (Castells, 2000). Castellaci et al. (2004) recognize that “a complete theoretical and analytical framework linking the different levels of aggregation is still missing”.

Previous studies that emphasize the decisive importance of “demand-pull” and at the same time minimize the potential effectiveness of “supply-push” policies did not stand strong enough, basically because of the broad use of the term “demand”, which encompassed all the determinants in the innovation process (not distinguishing technology-push up to include the elusive notion of “needs”) and ruled out almost other influences. As Rosenberg (1982, p. 229) puts it:

“An additional consequence of this confounding of need and market demand is the frequent failure to distinguish between motivations or influences upon the innovation process that arise from within the economic unit, such as those resulting from increases in output or changes in production technology, from factors that are external to the firm and mediated by the market”.

Empirical evidence drawn from a survey of 785 companies from China, North America and Western Europe, led Kanter (2002) to divide the companies between pacesetters and laggards. According to this study, “the pacesetters seemed to be ahead of change – capturing more benefits of change and often spending less to get more. The laggards were behind the competition and had more internal struggles about change. And when the laggards incorporated new technology into their business, it cost them more, and they often didn't get the benefit." Kanter (2002) also points out the entrepreneurship of middle managers to be aware of the environment and to convince the top management of their ideas. Corporate people have levels of denial, which say "We don't have anything to do with it".

If we follow the lead of Fagerberg (2004) when he says that what goes on inside the black box has a lot do with learning at different levels, we can find articles like the one of Harkema (2003), who regards innovation as a complex adaptive system for modeling purposes in order to study the phenomenon. The author used Repast software[26], to draw the following "practical implications"[27] of the theoretical ideas developed in the paper and the findings from the simulation mode (Hakerma, 2003, p. 345):

- "The organization of innovation process – instead of viewing innovation processes as a series of events and activities, innovation should be seen as an on-going process, a mentality, which needs to be channeled towards the development of commercial and successful solutions. This implies that teams will emerge spontaneously if a shared mental model has evolved through interaction. Commitment and trust are namely key resources and they can only evolve through interaction; they cannot be imposed.
- The decision-making process – processes do not solely consist of decision-making, procedures and information exchange but in as much of cognitive aspects of which knowledge sharing and exchange are the primary forces. Consequently processes need to be flexible enough to allow for individual

[26] Repast, according to Hakerma (2003), is a software framework for agent-based simulation created by the Social Science Research Computing Department at the University of Chicago. The software is available through the Internet. Its reference page is in http://repast.sourceforge.net/ .
[27] We quote only those related to processes.

> creativity and avoid structural inertia. Processes evolve through interaction and henceforth structures will be temporary, i.e. dissipative, and be created and re-created through the changing patterns of relations between people. This implies that management must allow structures to evolve and dissolve. This can only be accomplished if there is a high degree of trust among all the players involved".

Lately, Frenken (2006) discussed three families of complexity models of technological innovation, namely the fitness landscape models, the network models and percolation models[28], as being useful to analyze complex interaction structures while avoiding "over-parameterization". The author justifies the use of complexity theory in the study of technological innovation, for its interdisciplinary nature "can be readily understood from the fact that complex systems exist in natural worlds (fluids, ecosystems, and weather), social worlds (organizations, markets, and societies) and artificial worlds (technologies, institutions, and languages)".

Frenken (2006), acknowledging that complexity theory has become influential in recent models, for the study of social science, states that "the topic of the innovation process has received less attention" than the technology adoption and technology diffusion applications.

Every human being finds a big gap between creative ideas and its implementation. Walker and Henry (1991, p. 3) posit that there are three levels of obstructions or inhibitions that prevent creative ideas, inherently tied to every human being, from producing either tangible or other diffuse outcomes, such as new products, new services, new structures or changes in culture. Those three levels are located at the national level, with some countries generating, developing and promoting ideas that

[28] An example of a percolation model can be found in Silverberg and Verspagen (2005).

have a direct impact in their development; at the organization level, where the process of innovation is not very well understood, thus provoking some random bias on the outcomes; and finally at the manager's level, who show some anxiety in managing the process (ability to trigger, generate, control and steer new ideas throughout the maze) of innovation.

Kanter (1988) considers the three power tools in any "change master company":

- Information – is more available to more people at more levels through more devices;
- Support – organization should permit collaboration, so that people can build supportive, problem solving coalitions;
- Resources – high innovation companies tend to decentralize resources to make them more available for local problem solving.

Taken together, these perspectives can gain a behavioral focus, leading to a social phenomenon.

2.4.1. Scale of innovation

Scale is probably what makes innovation researchers diverge the most. If we conceive an onion model, where innovation is placed at the core of a multidimensional space, then we can develop several layers of subjects and activities around such core and build a framework around the focus of the literature. From the outside in, the first layer would include the activities of stimulus, conception, proposal and adoption (Becker and Whisler, 1967) or designing, managing and coordinating (Ethiraj and Levinthal, 2004) innovation efforts. Of course these activities are directly influenced by the socio-cultural mesh where the individuals who carry on these activities are inserted. Rephrasing the last sentences within the social network background (e.g., De Bresson and Amesse, 1991), we should rather say that innovation at the macro-scale, involves activities of design (e.g., Goldberg, 2002), managing (e.g., Walker and Henry, 1991) and coordination (e.g., Tomochi, Murata and Kono, 2005) which are the product of several social networks involving different types of individuals and organizations (agents) covering all the world.

Now if we move on to a meso scale, these activities are also present but are influenced by the political environment surrounding the agents, leading to development of concepts of National Systems of Innovation (Lundvall, 1992; Lundvall et al., 2002) and to the study of phenomena, such as diffusion, implementation, assimilation and so on of different types of innovation.

Moving further down to the sectoral level (Castellaci et al., 2004; Malerba, 2004) we find that "innovation greatly differs across sectors in terms of characteristics, sources, actors involved, the boundaries of the process, and the organization of innovative activities" (Malerba, 2004).

Then, we reach organizational innovation. Three research approaches are identified by Wolfe (1994), namely the diffusion of innovation, organizational innovativeness and process theory, each associated with a particular research question and with a typical research focus. We situate our work in the process theory field, but instead of associating the process with implementation as done by Wolfe (1994) we associate it with initiation phase as defined below.

Amplifying the first category, Wolfe (1994), based on the work of Rogers (1983) elicit six factors that influence the diffusion of innovation, namely: (1) adopters characteristics; (2) the social network to which the adopters belong; (3) innovation attributes; (4) environmental characteristics;(5) the process by which an innovation is communicated and (6) the characteristics of those who are promoting and innovation. The same author, based on Tornatzky and Fleischer (1990), introduce a classification of adopters “which are presumed to have different characteristics and tendencies to adopt”, as follows: “innovators, early adopters, early majority, late majority, and laggards”. Wolfe (1994) and other authors mention the S shaped curve of innovation adoption, picturing uncertainty reduction at first, the sharp rise pertaining the mimetic behavior of success and then a saturation. Following the history of diffusion of innovation, Wolfe (1994) notices that there was a shift from individuals (e.g. farmers, doctors, etc.) to organizations, claiming the “the process of diffusion of an innovation among organizations, however is very different from that among individuals”, without clearly stating why.

Wolfe (1994, p. 411) still recognizes the existence of identifiable innovation stages. This is important, since inside the process theory one can identify a stream concerned with the so called Stage Model, which led to the development of various stages being recognized. This diversity didn’t hinder the development of a general pattern. From the complete cycle we quote only the beginning, which is the relevant part for our study: “a decision-making unit becomes aware of an innovation existence, a problem or opportunity is matched to the innovation, the innovation’s costs and benefits are appraised, sources of support and or opposition attempt to influence the process, a decision is made to adopt (reject) the innovation…” (Wolfe, 1994, p. 411).

2.4.2. Spectrum of Innovation

A very common quarrel in the literature is what side of the equation takes precedence in the innovational process: demand-pull (need), dominant in IS innovation research (Lyytinen and Rose, 2003) or market- (technology-) push referred as "technological determinism" by Lyytinen and Rose (2003). This has caused an ever growing escalade of arguments on either side. Lyytinen and Rose (2003), call for a more holistic approach in understanding IS innovation, stating that "both push and pull forces is needed in order to explain the emergence of radically new types of IS innovations". They bring in the case of electricity (the infrastructure), without which there wouldn't be a demand for electrical apparatus. Over time, innovations in the electrical infrastructure acted as a push side that led to increased demand for more electrical appliances (demand pull) and further inventions on the infrastructure.

Another pertinent issue in the innovation literature is the diffusion of innovations, either internal, on nested functions or activities or external, on networks of innovation (Harris, Coles and Dickson, 2000; Lazer, 2003; Pittaway et al., 2004).

Carlisle and McMillan (2006) used a CAS perspective in suggesting that organizations need to "dance" between "the edge of chaos" and "the edge of stability" in case they want to build and sustain an innovational advantage. They propose the table that we reproduce as our Table 3, to illustrate their argument about the spectrum of innovation (Carlisle and McMillan, 2006, p. 4):

2.5. Methodological Questions

As stated before, we follow a co-evolutionary framework to study innovation phenomena. We drew arbitrary and naturally porous lines to divide de sub-fields that deal with innovation to guide our literature review. We now want to stress that culture drives technology (Castells, 2000), being the latter a manifestation of the first. Our study is then situated within the social sciences, in general, and in CMOT, in particular. As such, the real mechanism that drives innovation may never be completely understood. We solely have a perception of its presence and relevance, which leads to a critical interpretation of the real phenomena. We acknowledge that this poses some ontological questions[29], but those questions are not present in our study, since we are conducting computer simulations, which, by definition are micro or hypothetical worlds (Gonzalez, Vanyukov, and Martin, 2005) that function as a social lab to study particular issues. Literature about the scientific validity of this methodology is available from Bankes (2002), Berry, Kiel and Elliot (2002), Gotts, Polhill and Law (2003), Srbljinović e Škunca (2003) and Taylor et al. (2004).

The use of complexity theory helps in adding realism to previous models without sacrificing analytical rigor (Frenken, 2006). The advantages of using a CAS is that their primary characteristics are “learning and adaptability, spontaneous self-organization, and phenomena that emerge from the interactions among agents” (Axelrod, 1999). Although it was tried by McBride (2005), this author used an interpretative use of chaos theory to conclude that the concepts of this theory “offer valuable support in developing a coherent and meaningful story concerning interactions between information systems and their host organizations”. McBride (2005) finds it reasonable to employ the

[29] Cf. Cruickshank (2004).

metaphors and models applied in other organizational studies that fall under the umbrella of complexity theory to study information systems in organizations.

Table 3 – Types of systems and degrees of order and stability

Type of System / System Properties	**Totally random and without pattern**	**Chaotic**	**Complex (Zone of Emergent Complexity)**	**Hierarchical**	**Mechanistic**
Controlling mechanisms	None	Strange attractors	Largely self-organization	Command and control	Tight rigid controls
Nature of relationships between agents	Independent agents no detectable relationships	Random	Networked and highly connected	Formally dictated by top down directives	Fixed and Prescribed
Nature of interactions	Random and totally irregular	Some detectable regularities & patterning	Fluid and interdependent	Mostly dependent	Fully dependent
Outcome	Random changes and outcomes. Disintegration certain.	Instability-unpredictable changes and outcomes. Disintegration possible.	Flexible new order involving radical and or incremental changes	Stability-Incremental changes. Ossification possible.	Stability-Systems are resistant to change. Ossification Certain.
	Highly unstable				Highly stable

Source: Carlisle and McMillan (2006, p. 4)

Damanpour (1996) uses multiple regression analysis to study several sets of contingency hypotheses in dealing with organizational complexity and innovation, and rejects meta-analysis procedure as the one developed by Hunter, Schmit and Jackson (1982), on allegations that this methodology was limited to "testing individual hypotheses (i.e., the effect of one contingency factor at a time)".

Dawid (2006) defends an agent-based approach as an important tool to study innovation and technical change especially supported by two arguments. First, he says, "predictions of standard equilibrium models do not provide satisfying explanations for several of the empirical established stylized facts which however emerge quite naturally in agent-based models". Second, he continues, "the combination of very genuine properties of innovation processes call for a modeling approach that goes beyond the paradigm of a

Bayesian representative-agent with full rationality[30] and it seems [to him] that the possibilities of ACE[31] modeling are well suited to incorporate these properties". The properties alluded by the author and pertinent to our study are: "the dynamic nature of the process(es)"; "the special nature of knowledge"; and "the strong substantive uncertainty involved". The rational paradigm does not hold because the access to information and knowledge is not free in financial and in cognitive terms (Caraça and Carrilho, 1996).

What is needed then, according to Castellaci et al. (2004, p. 4), based in Hodgson (1993 and 1998) "is a 'non-reductionist' theory of innovation and economic growth, in which the different levels of analysis may coexist and interact". We address this issue at the linkage between professionals and decision makers, within a co-evolutionary process of transformation.

We will observe an interdisciplinary posture while progressing on our study. Innovation studies have used both qualitative methods of research, such as case studies, and quantitative techniques, like econometric and analytical models. The generalisability of a case study is obviously one of the weaknesses of this method. On the other hand, econometric and analytical models seek for more general results valid for a large sample of statistical units (firms, sectors, and regions), but the process behind each unit's performance remains unexplained. Castellaci et al. (2004) advance that computer simulations is one possible way to bridge the gap, as they are a "flexible tool through which it is possible to do both things, to reproduce a given historical path, and to explore the effects of variations in the model's parameters on the observed trend".

[30] One possibility of going beyond the full rationality is to take into account the concept of bounded rationality as developed by Simon (1959), and further discussed in Gigerenzer (2000), and Gigerenzer and Selten (2001).

[31] Agent-based Computational Economics.

Other aspect that must be considered is the methodological antagonism that exists between networks analysts that tend to use quantitative methods and interactionists that are favorable of qualitative methods (Gibson, 2005), because “it needs to maintain maximum openness to the myriad ways in which a given utterance can be precipitated, warranted, or otherwise occasioned by the talk preceding it” (Schegloff, 1987, cited in Gibson 2005, p. 1562).

Benchmarks for measuring innovation proliferate in the scholarly literature and in the official statistics, as is the case of the “trend charts”, the “innovation scoreboards”, “innovation surveys”, “bibliometrics”, “R&D expenditures”, “patents” and the like.

Measurement implies commensurability, as observed by Smith (2004). As we are instantiating an abstract model, this means that its abstraction doesn’t vanish in the instantiation process. Therefore, the results that we are looking for are not empirical, but experimental. Instead of looking at our results in terms of a large amount of manipulated outcomes, we stress that we will show the results of random matches, simulating the choices that managers must inevitably make. Those choices are based on judgment and experience, “which is what the managers are paid for” (Pavitt, 2001), and we are not looking for any quantitative hint for benchmark purposes, because, according to Kline and Rosenberg (1986, p. 279), “there is no single, simple dimensionality to innovation”.

Since we are dealing with novelty in the adoption stage of the IS/IT innovation, we depart from previous work that attempted to add rigorous demarcation lines, such as the six functionalist and the five non-functionalist views of information systems development approaches (ISDA), by Iivari, Hirschheim and Klein (2001), for our learning effort is designed to be cross paradigmatic and thus not immediately associated with any sub-categories of the research in the Management of Information Systems (MIS).

Nonetheless, this study may offer a bridge between behavioral science and design science (Hevner, March, and Park, 2004). Behavioral science seeks to explain and predict human behavior in organizational settings. This is endorsed in the interaction of agents in our model. Design science aims at the development of new innovative artifacts, and includes the simulation, where an artifact is executed through artificial data, in the experimental field as a pertinent design evaluation method (Hevner, March, and Park, 2004, p. 86).

Throughout this thesis, we basically follow the seven guidelines outlined by Hevner, March, and Park (2004, p. 83), namely: “design as an artifact”, “problem relevance”, “design evaluation”, “research contributions”, “research rigor”, “design as a search process”, and “communication of research”.

Chapter 3 – AN AGENT-BASED MODEL OF IS/IT INNOVATION

3.1 General Framework

From the work of Frenken (2006), who recognized three core models – fitness landscape, network, and percolation – at least four "research avenues" were identified:

- use of the three core models in adjacent topics;
- recombination among them;
- recombination between them and earlier evolutionary models;
- and empirical testing.

We took the recombination avenue of the three identified core models and earlier evolutionary models to study IS/IT innovation. Fitness landscape model is used, firstly because we use mutations in genotype space, when we introduce a new agent with completely new characteristics; secondly, our model has elements of "NK-systems"[32], developed by Kauffman (1993); thirdly, fitness landscape is used in the technology field as a synonym of efficiency. Complex network model is used because we are looking at the rate of innovation adoption and we presume there is an internal network of relationships among people inside the virtual organization, with different topologies, making it possible to measure distances between agents' nearest neighbors (regular graphs), some agents and others agents that are not neighbors (small world), and agents and random subset of other agents (random graph)[33]. Percolation model is used since this model is useful to model the dynamics of adoption (Stauffer and Aharony, 1994; Grebel 2004), which means there is a threshold above which the agents chose to adopt

[32] Systems with N elements in which each element is affected by K other elements (Frenken, 2006).
[33] These are the three "ideal types" of networks, identified by Watts and Strogatz (1998, 2002).

the innovations. Earlier evolutionary models such as the Expected Utility Model, because agents look for other better ranked agents in order to improve their utility.

As stated before in the previous chapter and according to Kanter (1988), information, support and resources are key issues, or power tools in any company that wants to accommodate change into its business. Exploring this assertion, we developed an ABM, with which we could run computer simulations to test Kanter's propositions, using a different methodology than the original. We also would like to situate our work in the IS/IT innovation field. Although adoption and implementations have attracted the attention of researchers, much less attention is given to the preexistence of factors that might have consequences in the subsequent stages. Particularly interesting are the studies that focus on resistance to implementations, e.g., Lapointe and Rivard (2005). Like these authors, we adopt the political variant of interaction theory, based in Markus (1983), trying to explain the outcome of the interaction between types of agents on a power (political) ground. Markus (1983) posited that "a group of actors will be inclined to use a system if they believe it will support their position of power" (Lapointe and Rivard, 2005, p. 462). We extend this proposition to the initiation phase and investigate the validity of the following assertion, and as such, taken as our research question:

The power of the knowledge workers in the decision to adopt an IS/IT innovation within an organization varies with the matching level of ideas between them and the top management, while being dependant of the transactions' depreciation rate, leading to a strong fluctuation of power when the environment is unstable.

We rely in two types of agents to conduct our study. Recognizing the fundamental role of the top management in this process, the first type simulates the top management.

Based on studies that put the IS/IT unit inside the enterprise at core of IS/IT innovation (e.g., Swanson, 1994) and acknowledging the increasing role that "enlighted" workers have on that process, we assume that many professionals have the power to influence decisions about IS/IT innovations. We are clearly endorsing the ISF, as a distributed function, as discussed in the paragraph 2.3 above, that several professionals might have, instead of focusing a particular mandate or certified IS/IT profession.

First and foremost, from here on, whenever we apply the word agent we are referring to a person (Coleman, 1999).

Our model includes two types of agents, the Decision Makers (DM) and the Knowledge Workers (KW)[34] and is applicable to Small and Medium size Enterprises (SME's)[35].

The DM is to be seen as a set of people who take decisions about IS/IT at the top of an organization. Acknowledging that the DM could be "enlighted" about IT/IS and as such take their decisions without any consulting function, this is to be seen as an exception rather than a rule in most business. Therefore, for the purpose of our study, we assume that the DM need some type of technical counseling or internal influence when taking decisions about IS/IT. Furthermore, we assume that not all the decisions are perfectly rational. Rather, they rely on the social network of leaders and specialized workers that share similar points of views about information systems and technology. However, we should see their decision, at a particular instant in time, as irreversible, taking into

[34] This expression was borrowed from Banker and Kauffman (2004, p. 291).

[35] Although our work is abstract and doesn't need any concretization, the first reason for this conceptual framework is that 98 per cent of Portugal's industrial fabric is made of SME (Caldeira and Ward, 2002). Second, there is some previous work about the adoption of innovation in SME's (O'Regan and Ghobadian, 2005), including IS/IT innovations (e.g., Caldeira and Ward, 2002). Third, the process we are addressing has an empirical base drawn from questionnaires sent to companies with a minimum of 500 employees and a maximum of 10,000 employees (Kettinger and Lee, 2002, p.81). There are other works on innovation in SME in other countries as is case of Sundbo (1996) in Denmark, Piergiovanni, Santarelli, and Vivarelli (1997) in Italy and Bharati and Chaudhury (2006) in the Boston area. Fourth, online services have also captured the attention of the public sector, and three dimensions of online innovation have been identified, explicitly in the pre-adoption phase, such as: perceived need, technical capacity, and risk mitigation (Hinnant and O'Looney, 2003). Finally, since there is the promotion of an innovation policy at the political level in Portugal and in the European Union (EU) we would like to have a slight contextual background in our study, to advance the innovation studies, expecting to reach some cumulative knowledge.

account the postulate of irreversibility of time, or the arrow of time, as it is also known, demonstrated by Ilya Prigogine in the thermodynamics field and later expanded to socio-economic models (Prigogine, 1993).

The KW is to be seen as a set of people who have some specialization in the IS/IT field and are in a position to influence the decision about the initiation (or adoption) of some new aspect of IS/IT. They include those that have a professional specialization in the field and usually group together in IS/IT department and other workers that are technological skilful and are spread throughout the organization.

Now, we address Wolfe's (1994, p. 406) prescriptions about innovation studies, as stated in section 2.1. We situate our study in process innovation, answering the first question, on "which of the various streams of innovation research is relevant to a research question". We already affirmed that we are focusing on the initiation (pre-adoption) stage, responding to what "stage of the innovation process upon which a study focuses". "The types of organizations included in a study" is actually an abstract one, since we are conducting simulations, but we have a generic SME, low-tech, service firm or public service in mind. We conceptualize two variables for the outcomes of the incumbent agents: Autonomy (A) in the decision making process for the DM group and Power (P) for the KW group. In the ABM that we describe bellow these variables are the reward of each group, subject to a certain depreciation adopted, from an equal initial endowment. This approach is to address Wolfe's question on "how a study outcome variable (e.g. adoption, innovation, and implementation) is conceptualized". As far as the reply for "the attributes of the innovation being investigated", those are the ones resulting from the interaction of the agents, specially the "empowering" of the KW, and "autonomy" of the DM, having in sight the efficiency of the decision making process of the whole enterprise as and end. This interaction can also be seen as the push and pull side of the innovation by anyone of the agents, in order to develop a more holistic perspective in understanding IS innovation, since both forces are needed for the explanation of radical new types of IS innovations, as argued by Kettinger and Lee (2002).

3.2 Model Description

We used a formal model, coded in the language of Matlab software, which is an instantiation of a model developed by Araújo and Vilela Mendes (2006).

In the model there are $2N$ agents: N knowledge workers and the same number of decision makers. Each decision maker has a set of needs of information coded by a string of k bits and each knowledge worker has a recommendation coded by a string of k bits. The bit string of a decision maker represents what the decision maker agent needs of information to receive from the environment and the bit string of a knowledge worker is a code for the recommendations that he is able to supply. Because no passive actors are assumed in the environment, the environment for each agent is just the set of all the other agents.

In addition to the two bit strings that code for needs of information and recommendations, each agent has a scalar variable A or P, depending on the agent type (decision maker or knowledge worker, respectively). The variable A represents the degree of autonomy on the decision making process and P represents the amount of power to influence the decision making process.

The dynamics of the model is characterized by exchange, evolution and adaptation. The basic driver of the exchange dynamics of the model is the matching between needs of information and recommendations. At each time step, the matching between needs of information and recommendations is made and each agent chooses at random one among the recommendations that better match his needs of information. The agent that has this recommendation is a potential assessor of the decision making process. That is

$$A_i(t+1) = A_i(t) - rDM + \frac{q_{ij}^*}{k} \tag{1}$$

$$P_i(t+1) = P_i(t) - rKW + \sum_{j(i)}^{k} \frac{q_{ij}^*}{k} \tag{2}$$

The index *j(i)* runs over all the agents *j* that are supplied by the agent *i*. On receiving a recommendation from the knowledge worker *i*, the decision maker *j* increases his Autonomy *A* by $\frac{q_{ij}^*}{k}$ – *rDM*. At the same time, the knowledge worker *j* increases his Power *P* by $\sum_{j(i)}^{k} \frac{q_{ij}^*}{k}$ – *rKW*, where *rDM* and *rKW* stand for two constants depreciation rate (or costs of living) that are subtracted at each time step from decision makers' autonomy and knowledge workers' power, respectively. The variable $\frac{q_{ij}^*}{k}$ stands for the matching of the knowledge worker *i* that assesses the decision maker *j*.

The above transactions, carried out at a level that only depends on the matching between recommendations and needs of information, represent the normal subsistence operating level of the system.

At each time step needs of information and recommendations are compared. The knowledge worker that assesses each decision maker is chosen at random among those with larger matching. When $P_i < 0$ this knowledge worker *i* disappears. When $A_j < 0$ this decision maker *j* is replaced by a new one with random needs of information string and $A_i = A_0$.

Once the number of surviving knowledge worker stabilizes, IS/IT Related Innovation (IRI) is possible through the matching (using the hamming distance) of recommendations of a particular knowledge worker who finds the decision makers that have a concordance level above a certain threshold and develop a new recommendation string (by flipping his worst bit) according to their need of information bits.

Finally, a decision maker only remains in the field as long as its Autonomy A is positive. If it becomes negative, he dies and is replaced by a new random agent. Initially all agents and the replacement agents are endowed with the same initial P_0 and A_0.

There are of course some important features of real decision making process that are not explicitly included in our abstract codification of the recommendations offered by each agent. For example, recommendations sometimes have some core features that are technical and some others that are adjustable. Then the agent may offer the same recommendation to different decision makers as different offerings. This particularity is particularly important in service organizations.

The choice preference in the model being achieved by maximization of the partial matching between recommendations and needs of information, my lead to the point of view that one is dealing only with the core features of the recommendations. An explicit coding of core versus adjustable features might be included by keeping some recommendations bits fixed and fuzzifying a few others. However, we believe that the qualitative dynamical features of the model would not be very much affected by this change.

3.3 Model Dynamics and Self Organization

The model also contains a dual mechanism for the evolution of the needs of information. On one hand there is a general mechanism of evolution of the needs of information that is not directly dependent on the exchange dynamics. It is implemented as follows: at each time step (after the exchanges) a k-bit string is chosen at random. Then each agent chooses at random one of his needs of information bits and makes it equal to the corresponding bit of the random string. If it is already equal, nothing happens to this agent. This mechanism that appears here as the working of some external influence (external environment) may, in a more detailed model, be also the result of an endogenous effect like partial conformity to some fashion. The second mechanism is one of partial adaptation or conformity with the available recommendations. Again, each agent takes one of his needs of information bits at random and changes it to make it equal to the majority of the same position bit in the recommendations.

3.4 Distances

In order to investigate the relationships among the agents, a series of distances are computed. The main purpose of this procedure is to investigate the structure of the two types of agents in two different time intervals. Before t=250, innovation is not present in the decision making process. Then, after t>=250, innovation is present in the interaction of both groups. Thus, a comparison is possible between a situation without innovation and the other one, where innovation is present.

The shorter the distances the more similar the agents are in the different subgroups, identified below. From the interaction between the two main groups, some type of structure will eventually emerge. We'll address the specific question: will we find some type of stucture(s) more prone to the success of IS/IT innovation?

We use the hamming distance, to calculate the percentage of coordinates that differ between vectors. Then, the squareform function is used to produce a square matrix from the vectors created by the distances calculation. All the distances presume a Mean Concordance Level (MCL), given by the hamming distance, equal or above to 4 bits between the agents, at first. Although other distances were used during the trials, here we report only the more relevant ones for our investigation. In order to find some correlation among the variables, first we've measured the mean distance among DM needs of information, M1. Then, we look at the distances between the KW who survived the process, M2. Finally we've compared four pairs of distances before innovation was allowed and after innovation, as explained earlier. The first pair of distances was the mean distance between the KW who did IRI and those who survived the process, M3 and M4. The second pair is the mean distance between the KW who did IRI and the others, M5 and M6. The third was the mean distance between the KW who did IRI and those above the *MCL*, M7 and M8. The fourth was the mean distance between the KW who did IRI and the needs, M9 and M10.

A summary of these distances is represented in Table 4.

3.5 Hypothesis formulation

Fagerberg (2004) calls for conceptual research to be made at the organization level, since understanding of how knowledge and innovation operates remains fragmentary.

We took Castellacci et al. (2004) lead regarding the systematic approach in innovation studies and focused our research at the organizational level, clearly focusing the innovation process inside the Management Science. Although there are claims that a new academic field has emerged integrating electronic computing, digital data, decision support systems or generic systems that connect people, business process, firms, industries, and markets, essentially IS/IT affect all management functions (Banker and Kauffman, 2004).

Table 4 – Distances among agents, including some auxiliary constructs.

Distance	Meaning
M1	Mean distance among DM needs of information.
M2	Mean distance among KW that survived the process.
M3	Mean distance between the KW who did IRI and those who survived the process.(BEFORE)
M4	Mean distance between the KW who did IRI and those who survived the process.(AFTER)
M5	Mean distance between the KW who did IRI and the others.(BEFORE)
M6	Mean distance between the KW who did IRI and the others.(AFTER)
M7	Mean distance between the KW who did IRI and those above the *MCL*.(BEFORE)
M8	Mean distance between the KW who did IRI and those above the *MCL*.(AFTER)
M9	Mean distance between the KW who did IRI and the needs of information. (BEFORE)
M10	Mean distance between the KW who did IRI and the needs of information. (AFTER)

We will not address the diffusion of innovation outside the organization, at the institutional level or the impacts of the success of the innovative firm in the scales above. That has been done in a number of other studies (e.g. Castellacci et al., 2004).

In the model we conceptualized, agents are persons and as such they exhibit differences that manifest itself on the roles they play and in the sociability with their partners or managers, in an organization. Thus, the counseling provided by the KW to the DM is expected to vary considerably, producing an impact in the success of the decision making process to adopt the IS/IT innovation. The same goes for the perceived utility of that counseling. Sometimes the KW has a useful piece of information, but the managers don't find it too attractive and discard it. Other times they may overestimate the information that is being provided, and they take the decision to adopt it. When searching for relevant, pertinent, timely and accurate information, they may or may not find it. For the purposes of our study, in the beginning all agents are in a similar position, that is, all of them have the same initial endowment, or capabilities. After some time (t=250) they are allowed to innovate, so:

H1a – Being the characteristics of the agents (the strings representing them) randomly generated, will there be uniform outcomes (normal distributions) for the Power of the KW and Autonomy of the DM?

H1b – Can a raised depreciation value (*rDM*) explain any difference in those outcomes?

Later (H3 e H4), we will explore the effect of these circumstances on the organizational setting, under instability.

As the differences in the counseling produce different success' stories for the DM, among the KW some will see their power to influence the decisions grow, others will see it worsen. The higher the Autonomy of the DM, the better top management knows (is informed) how to decide without their collaborators. If there were no changes, a linear model could be used. With random values, the matching mechanism holds the key to explore uncertainty. In addition, since we are investigating IS/IT innovation which is mainly brought into the organization by the KW, an adaptation of the DM can be tested. We have set firstly a threshold of 4 bits of mean coincidence between agents to allow the adaptation to happen. If the right KW is picked to influence the decision, then a better use of the IS/IT resources can be claimed. Thus:

H2a – Will differences in Power among the KW be observed?

A higher level of empowering of the professionals can be correlated with a better use of the human resources affected to the ISF.

H2b – Can the quantity of Power of the KW be adjusted with quantitative variations in at least two parameters: the depreciation value (*rKW*) for each recommendation and the threshold used for matching (adapt) to the needs of the DM, when IRI occurs?

H2c – Is this last parameter only applicable when IRI results from the adaptation of recommendations offered by the KW to the needs of information by the DM?

Other two relationships may be anticipated. First, we anticipate a relationship between the mean quantity of Power and the number of active KW. Second, we anticipate a relationship between the mean growth rate of Power and the proximity of the DM who succeeded in their decisions with those KW. Consequently:

H3a – Are there any correlations between the mean growth rate of Power of the KW who respond efficiently to innovations induced by new needs of information and the number of active KW?

H3b – Are there any correlations between the mean growth rate of Power of the KW who respond efficiently to innovations induced by new needs of information and the proximity of the DM who recurrently uses the services of those KW?

H3c – Can those correlations be explained by any dissimilarity of the agents?

Another situation is when there is a rise in demand for information, provoked by changes in the environment. A situation where DM have to deal with a new or unforeseen event, under time pressure, or other contingent situation, can be envisaged. As a consequence, transactions costs, or depreciation cost for the DM (*rDM*) may be higher. Then, one can expect a different type of behavior from the agents, namely:

H4a – Are there any correlations between the growth rate of Power of the KW who respond efficiently to innovations induced by new needs of information and the number of active KW?

H4b – Are there any correlations between the growth rate of Power of the KW who respond efficiently to innovations induced by new needs of information and the proximity of the DM who recurrently uses the services of those KW?

H4c – Can those correlations be explained by any dissimilarity of the agents?

Since one of the bases of our model is the matching mechanism between KW and DM, the stipulation of the threshold is the key to provoke successful encounters between agents. One can anticipate that when that threshold is established above a particular value, no successful innovations can be obtained, and:

H5a – Will there be no correlations when the matching threshold established between the recommendations and the decisions is high (above 50%) between the innovators success rate and any other characteristics mentioned in the previous hypotheses?

H5b – Will the innovation be less rewarding in a highly demanding environment for the DM who innovates, even if the instability conditions mentioned in H4a and H4b above are present?

These hypotheses will be tested using the model described above, in order to assert the value of our research question. The results of the simulation and a discussion around them will be discussed in the following chapter.

Chapter 4 – RESULTS AND DISCUSSION

4.1 – Results of the simulations

In this section we report the results of the simulations. Being the key to our simulation, different values of *MCL* were used for the purpose of segmentation the results representation. Several tentative values were first tried before establishing *MCL* in 40%, 60%, and 80% as illustrative of typical settings. Then, for each of these *MCL* values, three environments were chosen, based on three values of *rDM*. The same tentative procedure was used to establish *rDM* values in 0.5, 1, and 1.3, determining different regimes, to simulate stable, volatile and highly volatile environments, respectively. In those three environments, both values of depreciation and matching level are shown on top of each chart. For each situation, the Power growth rate (the "reward" of the KW) of those agents who survived the process is illustrated on a diagram as typical graphic. Another diagram displays the Autonomy (the "reward" of the DM) of agents across the iteration time, also as a typical illustration. This chart is useful to demonstrate the volatility of the environment as dependent of the depreciation value per iteration of the Autonomy of the DM (*rDM*). For each chart resulting from the simulations, the relevant statistical distance found can be seen on the bottom of that graphic, as well as the correlation coefficient that is shown above the graph. The last objective of the plotting of the simulations results was to find the relationship between the mean distances found in the correlations search and the efficiency of the innovation process. In the case of such correlations exist then a histogram is used to observe how the IRI efficiency is distributed through the 200 runs.

Figure 2 – A Stable Environment (*rDM*=0.5; *rKW*=0.5; *MCL*=40%)

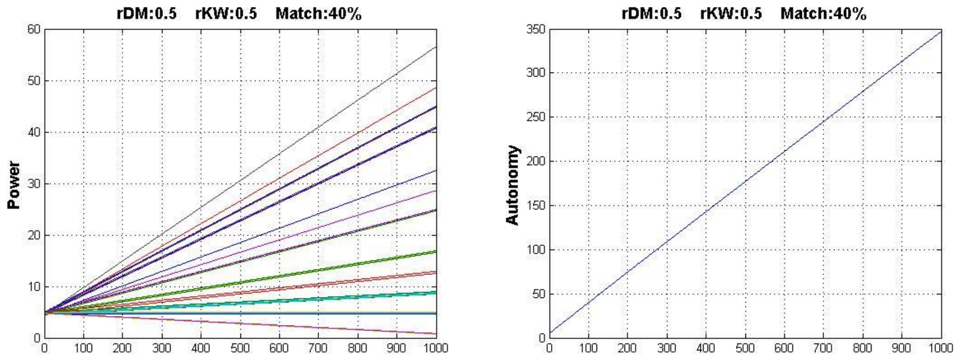


Figure 3 – Correlations on a Stable Environment (*MCL*=40%)

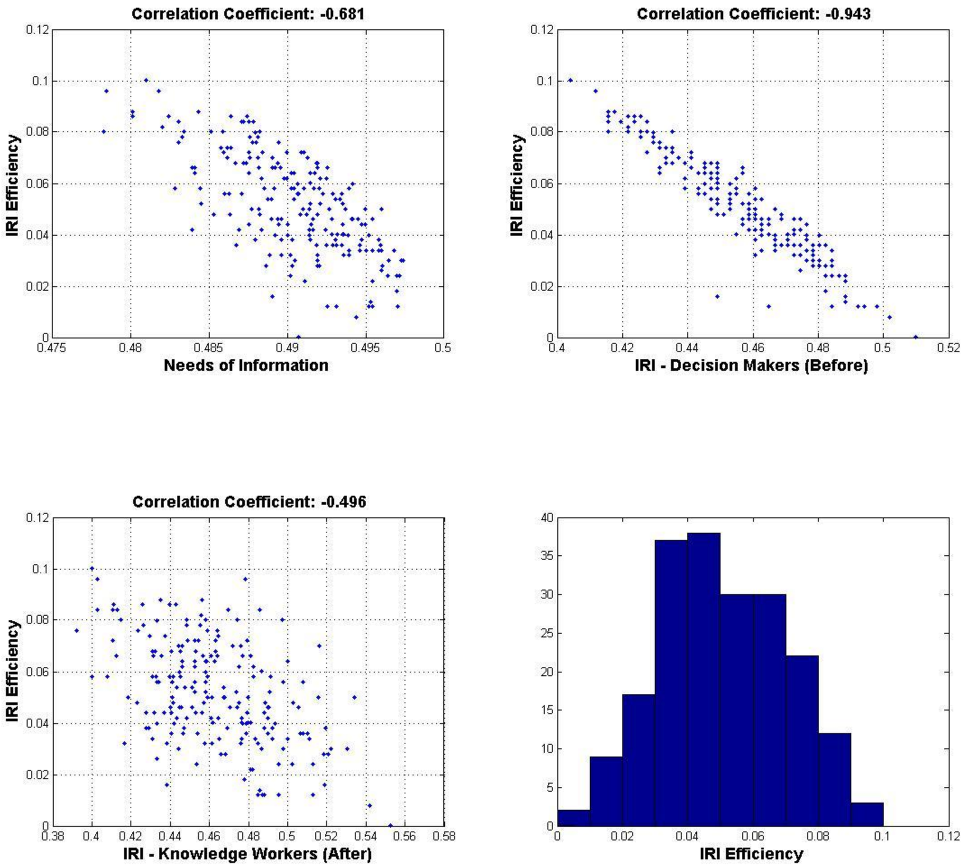


Figure 4 – A Volatile Environment (*rDM*=0.5; *rKW*=1; *MCL*=40%)

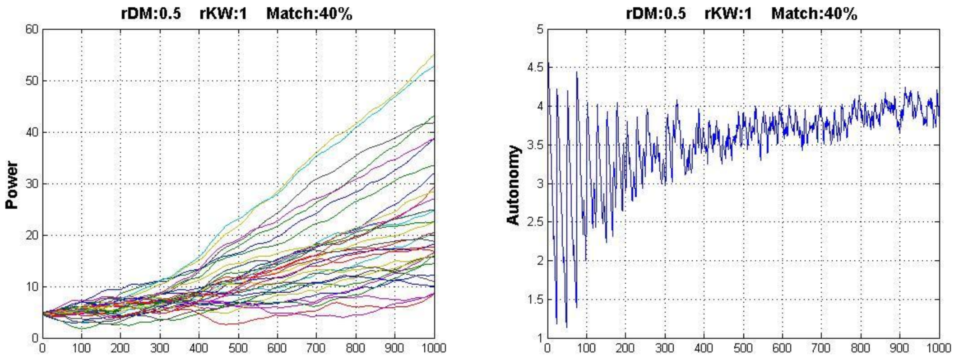
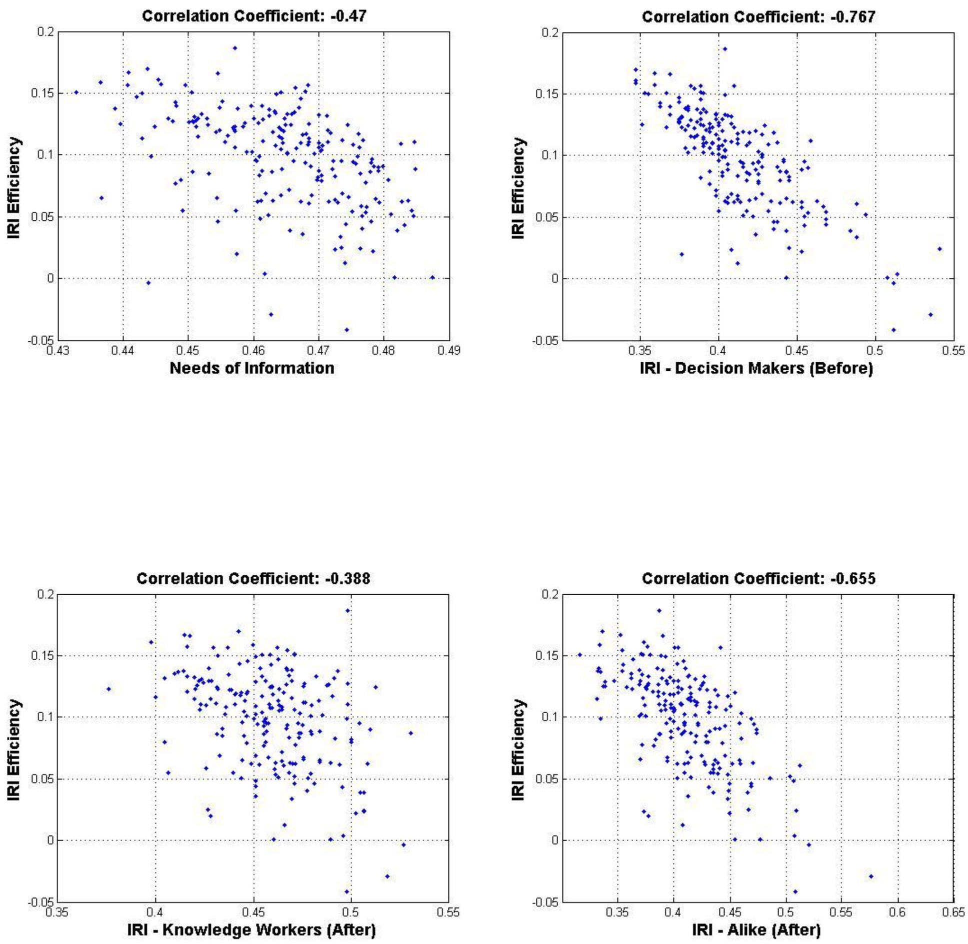


Figure 5 – Correlations on a Volatile Environment (*MCL*=40%)



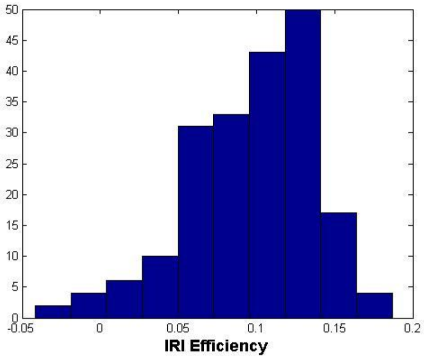
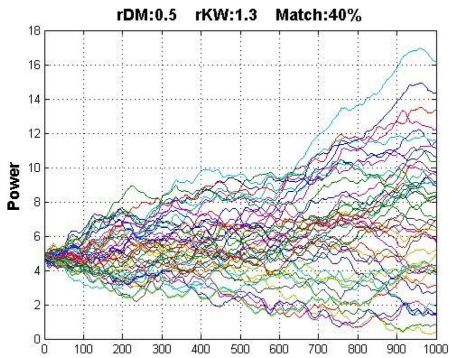


Figure 6 – A Highly Volatile Environment (*rDM*=0.5; *rKW*=1.3; *MCL*=40%)



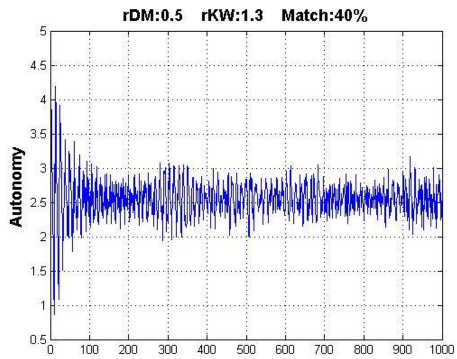
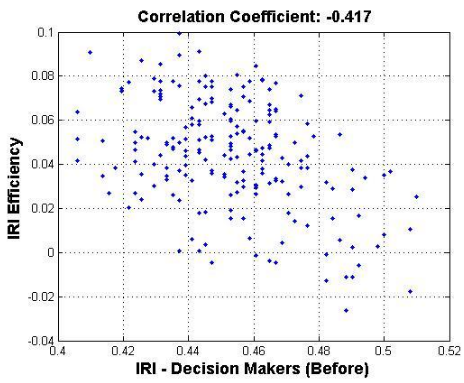
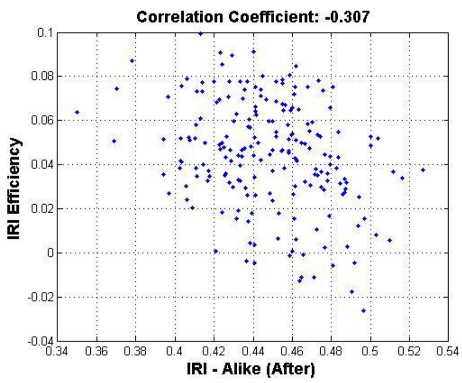


Figure 7 – Correlations on a Highly Volatile Environment (*MCL*=40%)





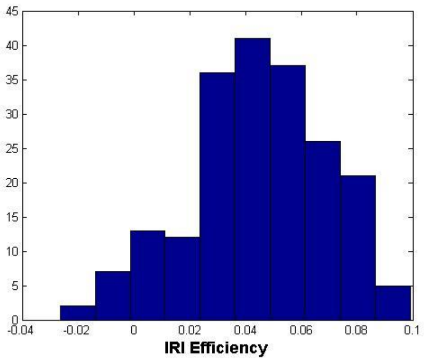


Figure 8 – A Stable Environment (*rDM*=0.5; *rKW*=0.5; *MCL*=60%)

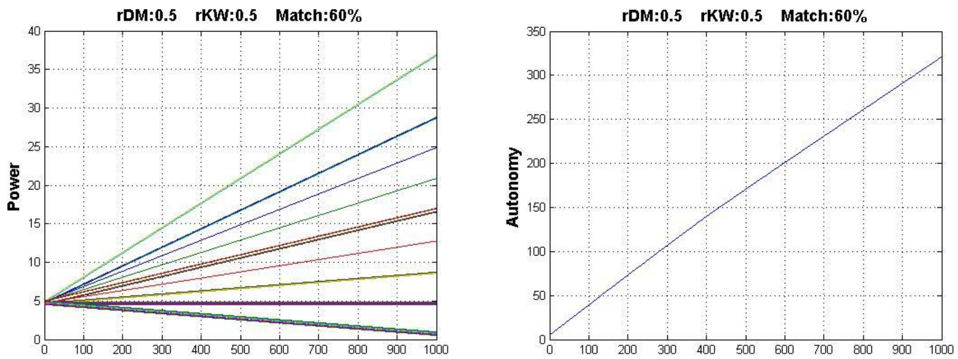
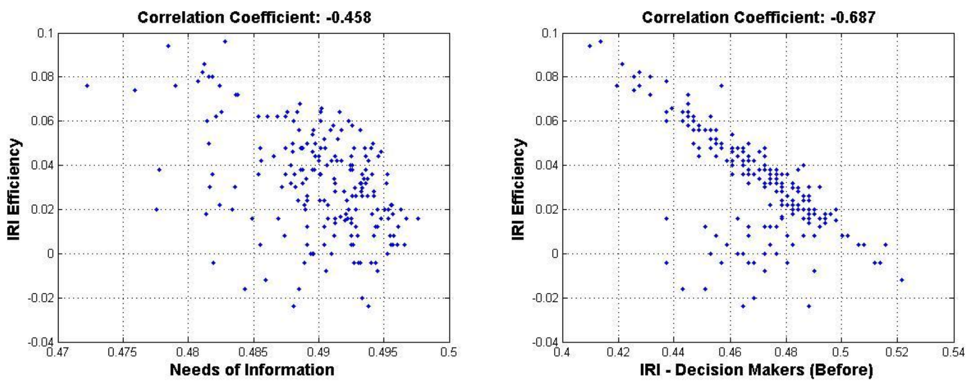


Figure 9 – Correlations on a Stable Environment (*MCL*=60%)



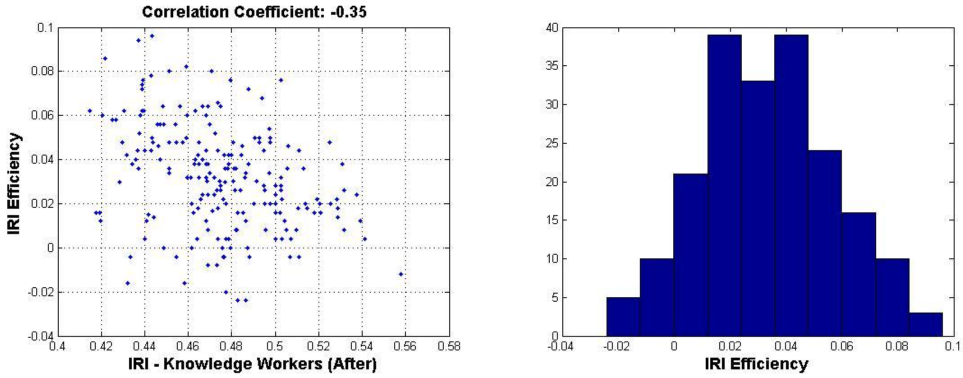


Figure 10 – A Volatile Environment (*rDM*=0.5; *rKW*=1; *MCL*=60%)

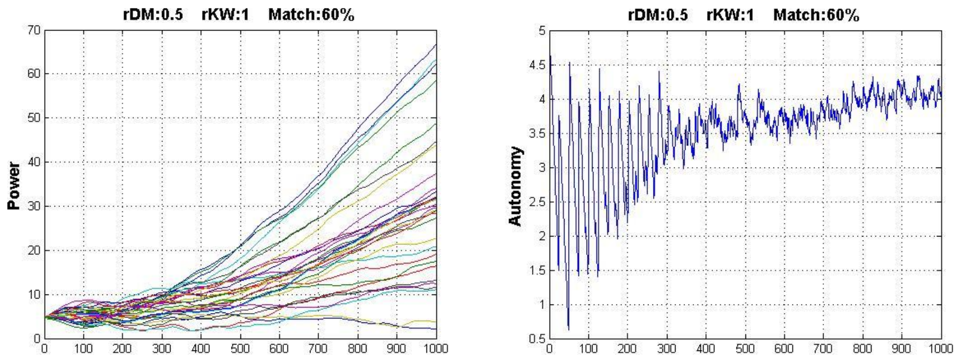
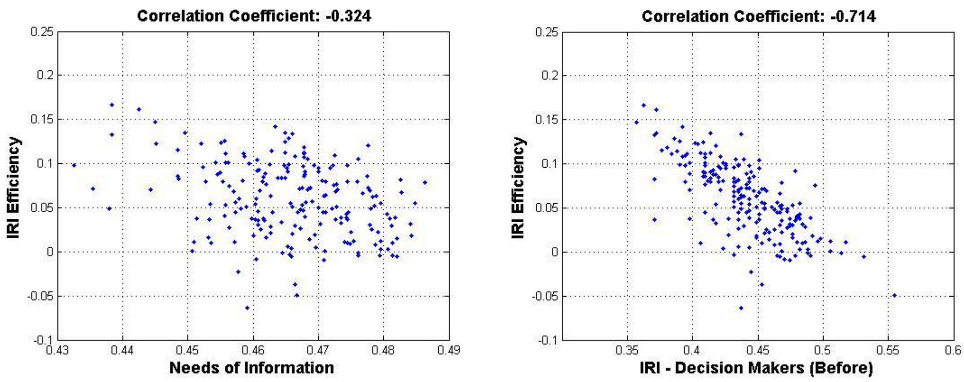


Figure 11 – Correlations on a Volatile Environment (*MCL*=60%)



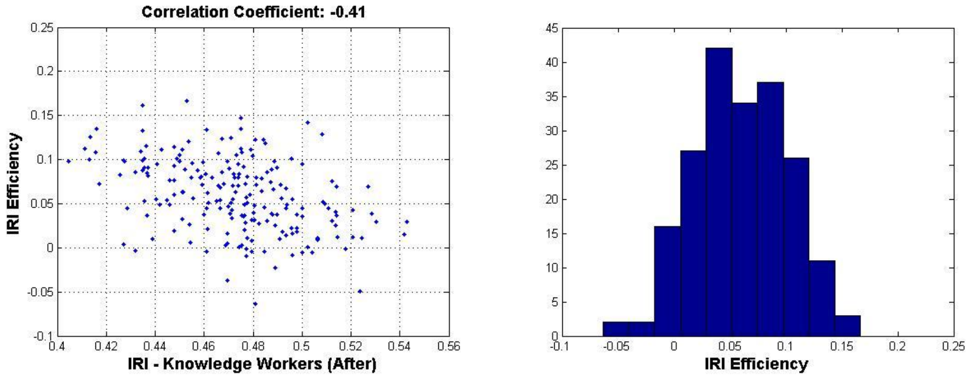


Figure 12 – A Highly Volatile Environment (*rDM*=0.5; *rKW*=1.3; *MCL*=60%)

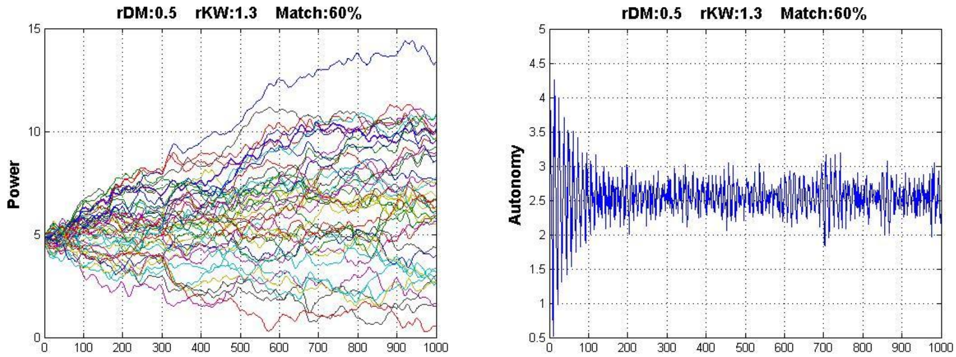
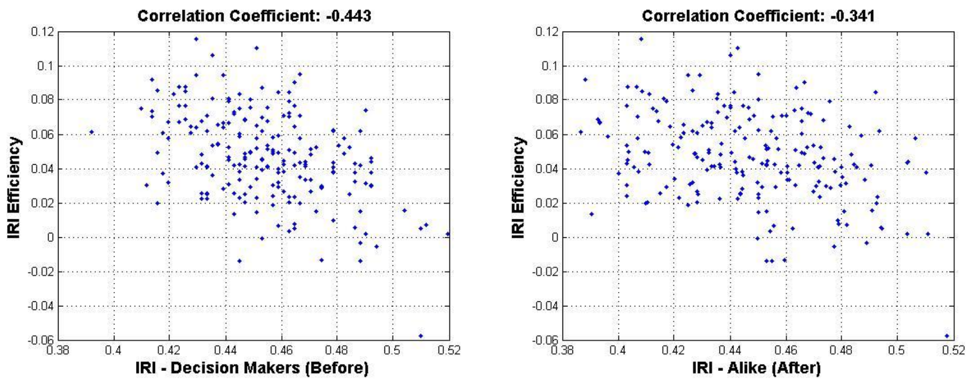


Figure 13 – Correlations on a Highly Volatile Environment (*MCL*=60%)



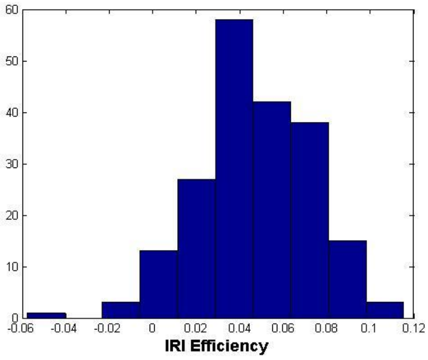


Figure 14 – A Stable Environment (*rDM*=0.5; *rKW*=0.5; *MCL*=80%)

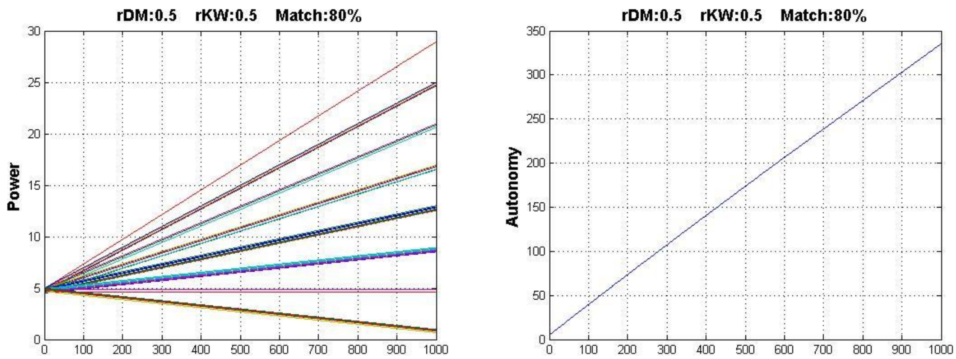


Figure 15 – Correlations on a Stable Environment (*MCL*=80%)

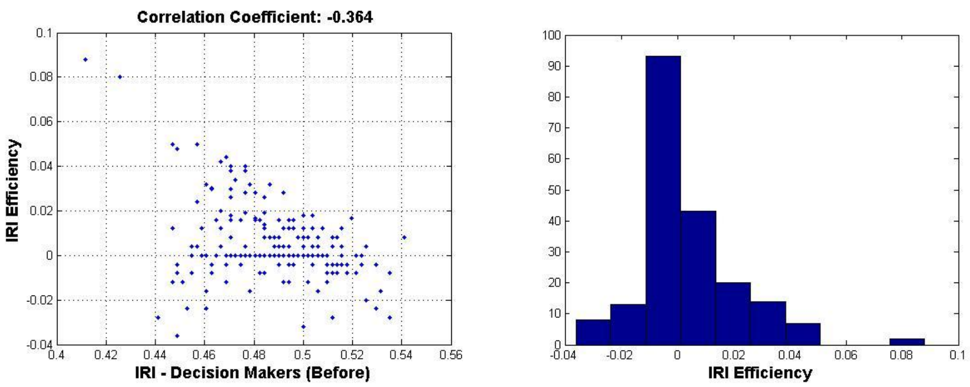


Figure 16 – A Volatile Environment (*rDM*=0.5; *rKW*=1; *MCL*=80%)

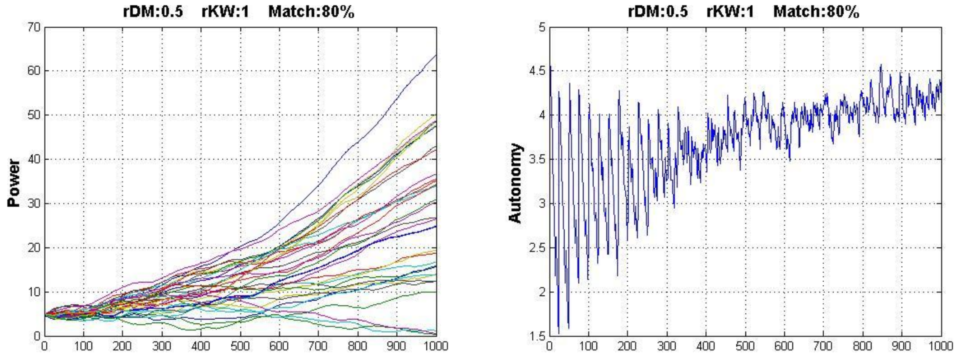


Figure 17 – Correlations on a Volatile Environment (*MCL*=80%)

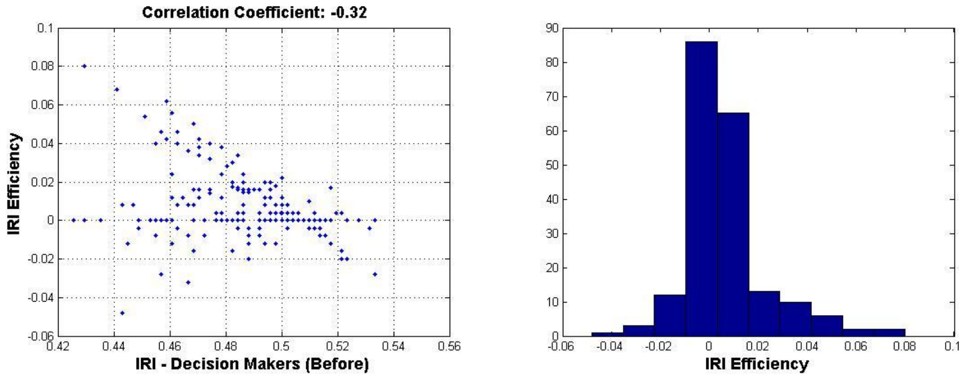


Figure 18 – A Highly Volatile Environment (*rDM*=0.5; *rKW*=1.3; *MCL*=80%)

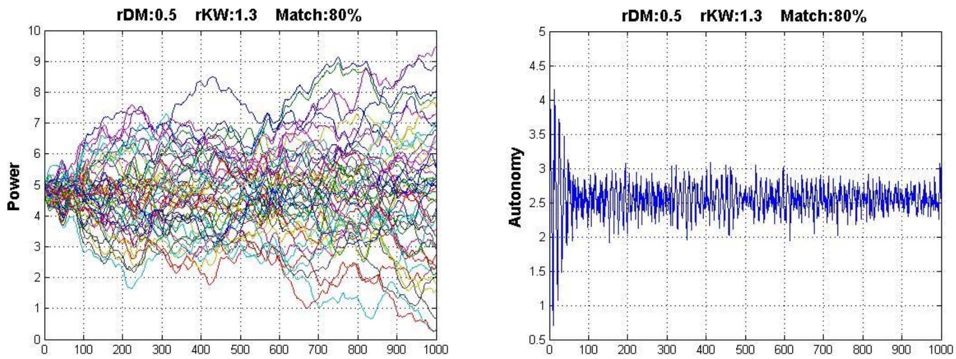
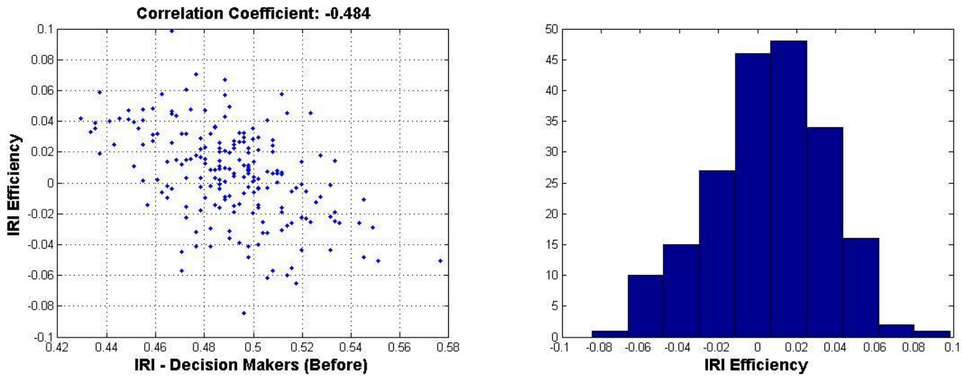


Figure 19 – Correlations on a Highly Volatile Environment (*MCL*=80%)



4.2 – Verification of Hypothesis

Based on the simulations depicted in the previous section we now discuss the verification of the hypotheses.

H1a questioned if the outcomes (Power of the KW and Autonomy of the DM) would be uniform (normal distributions) according to the characteristics of the agents (randomly generated). Through the simple observation of the illustrations, specially the histograms, one can immediately support this hypothesis, since randomly generated characteristics produced approximately normal distributions. **H1b** asked if a raised depreciation value (*rKW*) explain any difference in those outcomes. This hypothesis is supported because all the outcomes with *rKW* values of 0.5, 1, and 1.3, respectively, generate different stability regimes. *rKW* is the value responsible for the differentiation of environments, namely the stable, volatile and high volatile. The stable can be characterized for a straight line as representative of the Autonomy of the DM; the volatile environment is identified when there are oscillations in the Autonomy, but the function can still be seen as growing over time, if a mean line is drawn; when the oscillations are around a more constant mean value, then we can define the environment as being highly volatile.

H2a inquired if differences in Power among the KW could be observed. Independently of the condition, any Power diagram previously represented illustrates that there are Power differences among the KW, thus supporting the hypothesis. **H2b** advanced the supposition that the quantity of Power of the KW could be adjusted with quantitative variations in at least two parameters: the depreciation value (*rKW*) for each recommendation and the threshold used for matching (adapt) to the needs of the DM, when IRI occurs. The hypothesis is supported both for the depreciation value and the matching level as illustrated by the comparison of figures where these values differ. **H2c** questioned if the matching level parameter was only applicable when IRI resulted from the adaptation of recommendations offered by the KW to the needs of information by the DM. This hypothesis is supported as Power outcome can be observed and interpreted as an adaptation of the KW to the needs of the DM.

H3a raised the question if there would be any correlations between the mean growth rate of Power of the KW who respond efficiently to innovations induced by new needs of information and the number of active KW. The correlation was found in stable and volatile environments. Therefore, we can posit that this hypothesis is supported by the results of the simulation. **H3b** questioned if there would be any correlations between the mean growth rate of Power of the KW who respond efficiently to innovations induced by new needs of information and the proximity of the DM who recurrently uses the services of those KW. This hypothesis is corroborated, since the correlation between IRI efficiency and the DM is present in all simulations. **H3c** questioned if the correlations could be explained by any average distance among the agents. The mean distance between the KW who did IRI and those who survived the process (before) can explain the correlations found, since it was found in all simulations, supporting the hypothesis.

H4a inquired if there would be any correlations between the growth rate of Power of the KW who respond efficiently to innovations induced by new needs of information and the number of active KW. Such correlations were only found with *MCL* at 40% in volatile and highly volatile environments. Thus the hypothesis is partially supported. On the other hand, **H4b** asked if there would be any correlations between the growth rate of Power of the KW who respond efficiently to innovations induced by new needs of information and the proximity of the DM who recurrently uses the services of those KW. As said before this hypothesis is corroborated, since the correlation between IRI efficiency and the DM is present in all simulations. Similarly **H4c** questioned if those correlations could be explained by any mean distance among the agents. Just like **H3c** above, the mean distance between the KW who did IRI and those who survived the process (before) can explain the correlations found since it was found in all the simulations.

H5a focused on the matching level to raise the question about the existence of correlations when the matching threshold established between the recommendations and the decisions is high (above 50%), between the innovators success rate and any other characteristics mentioned in the previous hypotheses. As shown by all the simulations with the matching levels of 60% and 80%, the answer is affirmative, thus supporting the hypothesis. **H5b** specified a highly demanding environment (raised *MCL*), under instability conditions (raised *rKW*), to ask if the innovation would be less rewarding for the KW who innovates. Based on the lack of negative correlations, present on the other conditions, except for the one existing between the KW who did IRI and the position of DM before (IRI – Decision Makers (Before)), one can partially reject this hypothesis.

Table 5 resumes the verification of the raised hypotheses and its sub-divisions and synthesizes the analysis done.

Table 5 – Summary of the verification of the hypotheses.

Hypothesis	Sub-Hypothesis	Result
H1	**a**	Supported
	b	Supported
H2	**a**	Supported
	b	Supported
	c	Supported
H3	**a**	Supported
	b	Supported
	c	Supported
H4	**a**	Partially Supported
	b	Supported
	c	Supported
H5	**a**	Supported
	b	Partially Rejected

4.3 – Discussion

In this section we discuss the outcomes of the simulations. Taken together, the results show:

- Firstly, that only a percentage of the managers have their information needs satisfied by the collaborators, and that this rate is sensitive to the depreciation (fixed costs) used per transaction, leading to a situation of extreme instability with an excessive fluctuation of needs, either by the changing needs of information of the top management or a change in the environment;

- Secondly, that exist differences in the final Power of the collaborators, with this quantity capable of being adjusted with quantitative variations in at least two parameters: the depreciation of each recommendation and the threshold used for matching the information needs of managers, when an information technology innovation occurs;

- Thirdly, the leading factor to cause instability is the fixed depreciation costs of the KW;

- Fourthly, that a negative correlation between IRI efficiency and the number of active KW was present in less severe environments;

- Fifthly, there exists a measure in the structure of the agents that is present in every condition and simulation, IRI – Decision Makers (Before).

From the above, one can conclude that IRI is not very efficient in an organization with the management needs of information very stable. Negative correlation of the innovation efficiency with some measures, as illustrated in the previous section tends to indicate that adaptation between KW and DM in stable environments is symbiotic, since both Power and Autonomy augment during the process.

This type of innovation is most successful in an environment volatile (that is changing rapidly). However, when the environment is highly instable the innovation efficiency diminishes. This effect can be seen through the comparison of the averages on the histograms. Clearly, there is a rise in the mean efficiency from stable to volatile environments followed by a decrease in the efficiency when the environment is highly volatile.

From the verifications of hypothesis one can claim that the power of the knowledge workers in the decision to adopt an IS/IT innovation within an organization varies with the matching level of ideas between them and the top management, while being dependant of the transactions' depreciation rate, leading to a strong fluctuation of power when the environment is unstable.

4.4 – Further Work

This study has several limitations. The first is on the number of agents, since we only considered two types of agents. Then, we have considered a symmetrical setting, with both types of agents. The obvious expansion of this study would lead to include other type of agents (stakeholders of the firm) and asymmetrical settings.

The second limitation is on the type of environment considered. Although we conceived the random generation of the agents' characteristics as a possibility to see the environment as an open one, every agent was able to find matches with any other. Everyone knew about everybody else and passive agents were not considered. Taking into account the bounded rationality principle, would the results obtained still hold?

The third limitation is on methodological grounds. Simulations are good to study concepts "in the lab" and to advance theory, but the definitive proof of validity remains on empirical observance. From this study, several questions may be raised in order to obtain the "reality check", including the verification of the hypotheses through the means of questionnaires to decision makers and knowledge workers, broadly defined.

To avoid reductionism in this work we took a generic SME firm as a whole and as a background for our study. Since there are other studies addressing different scales, one large avenue of enquiry is immediately ready for scholar interest: establishing the links among the micro-meso-macro scales of observation. One possible way to obtain a link is the use of the allometric perspective advanced by Wolpert and Macready (1997, 2004), who suggests the self-dissimilarity between scales as an empirical complexity measure. Thus, an important research question is: “what pair of scales represents the most complexity measure?”. The answer to this question, would lead to a better focus of innovation studies, especially if one is looking for predictability of the innovation process, given that a high level complexity can lead to raised levels of uncertainty. This challenge can also be found in Castellacci et al. (2004) without the authors suggesting a possible way out. Among others, methodological challenges, according to the authors, reside in the need for systematic interactions between the levels of analysis.

Chapter 5 – CONCLUSION

The introductory stance located our work within organizational studies. Specifically, Computational and Mathematical Organization Theory was the stream identified, since we used a formal model to study IS/IT innovation within an organization. Two basic models were primarily used to develop our own that can be best described as a simulator in line with the sense that this word has in Gilbert and Troitzsch's (2005). The first model came from Daft and Weick (1984) and suggested that the organization was an interpretative system, pointing towards the cognitive perspective of interaction within social endeavors; the second was a highly abstract model, developed by Araújo and Vilela Mendes (2006) with the economic field in sight. The former was used because it is at the base of the change process and as such useful for innovation studies. The later was used due to its trans-paradigmatic approach to innovation that sought instantiation. This particularization makes it possible to address some less studied relationships as is the social mating inside a generic organization on political grounds. Since organizations are a peoples' creation to pursue some aim, we approached the IS function broadly and avoided reductionism, including both IS and IT as intricate and brought by people into the organizational realm.

We have conducted a brief summary of the relevant innovation research literature and observed that a thorough literature review was virtually impossible, with some authors offering a guide, instead of a review. Of particular interest is the systemic view of organizational innovation offered by scholars since the 60's. We gave references to some broad reviews of the field.

Addressing the ontological questions, we started by defending the critical realism philosophical stand point. We argued that social simulation was "normal" science, based on the Popperian theory of falsification. The critical realism can also be used as a philosophy for information systems. We revealed several definitions of innovation found on the literature. We have distinguished innovation from the normally associated terms of invention, improvisation and applied science and elicited and followed the prescription of Wolfe (1994) for reduction of ambiguity in innovation studies. Creativity was found to be a useful concept that is associated with idea generation, a common necessity for innovation, which is linked to the views of entrepreneurship and the psychological ground of earlier Schumpeterian studies. We stated that, for the purpose of our study, innovation was twofold. Firstly, it happened in the random generation of the characteristics of the agents, which by the very simple nature of the randomness meant novelty for the system. Subsequently, a search happened, followed by a matching mechanism. Selection came next. Then, innovation was provoked by the substitution of the agent with the poorest performance by another with the worst characteristic flipped so it can adapt to the needs of the decision makers. With such definition we have guaranteed that an evolutionary mechanism could be studied, because we can say that our model is an evolutionary model, within the ecological stream, given that we suppose a symbiotic relationship between top management and knowledge workers.

Reviewing the IS/IT innovation literature we have found that a wide range of definitions is also available in the literature. We operationally defined IS/IT innovation as a novelty to the top management and or to the professional that are connected by means of some working relationship through organizational ties that are somehow related to the particulars of Information Systems, Information Technology or Information Systems Functions. We cited several studies addressing IS/IT innovation, including the idea of the “dominant paradigm” by Fichman (2004a), having economic-rationalistic models as a basis. Taken this author’s challenge to explore issues outside the “dominant paradigm" we picked up a generic research question launched by him: "Which holistic combination of factors explain IT innovation outcomes, especially in cases where there are smaller numbers of large scale events with more extreme outcomes (i.e., dramatic success or failure)?".

A central topic is IS/IT innovation is the decision making process, thus bringing to bear individuals with different empowerment. From the theories available only Rogers (1983) with the Innovation Diffusion Theory addressed both the adoption by individuals and by organizations. A recent study (Jeyaraj, Rottman and Lacity, 2006) found that the linkages between individual and organizational IT adoption at the level of the independent variables were very weak. Top management support was the only good predictor for both types of adoption. From their study, we took two prescriptions related to linkages ("use environmental characteristics in individual adoption research" and "increase the study of rate of adoption as a dependent variable in individual adoption research") and one related to biases ("increase the study of "outcomes" as a dependent variable in both individual and organizational adoption research to overcome the pro-innovation bias") in order to give sense to our study and the ability for being modelled for simulations purposes that these prescriptions denote.

As said the process of decision making is at the core of the IS/IT innovation adoption, and is described as an "exercise in the management and reduction of uncertainty" (Kline and Rosenberg, 1986, p. 75). We have depicted several "Interactive Innovation Frameworks" from Manley (2003), assuming that in our work innovation process was dynamical and complex, meaning that success and failure are the outcomes of the interaction among many agents deeply intertwined and often deeply uncertain. An information system was presumed to exist either explicitly or implicitly and based on Pavit (2004) we posited that "innovation [was] (…) essentially a matching process". We have adopted Van de Ven (1986, p. 591) definition of process of innovation, which is "the development and implementation of new ideas by people who over time engage in transactions with others within an institutional context", discarding the implementation phase.

We also took the stance that our virtual organization was already a Complex Adaptive System, basing our approach to political grounds on Kettinger and Lee (2002), who state that "to a large extent, deciding who actually drives IT adoption depends on the power and influence users and the ISF has over IT planning and resource allocation".

To locate our study in contemporary research we refer to Frenken (2006), who acknowledges that complexity theory has become influential in recent models for the study of social science. The author refers that "the topic of the innovation process has received less attention" than the technology adoption and technology diffusion applications. We have also discussed two associated themes within the process of innovation, namely the scales of innovation and the spectrum of innovation.

Addressing the methodological questions we defended the use of the simulation and the Agent Based Approach that we used on our study, observing an interdisciplinary approach, in our quest to advance theory through experimental data. Our work was designed to be cross paradigmatic and to offer a possible bridge between behavioral science and design science.

Our stated purpose could be reached through the instantiation of the ABM from Araújo and Vilela Mendes (2006). This model was found useful to simulate the pre-adoption setting of IS/IT innovations or IRI. The ABM, with two highly stylized agents, the Decision Makers and the Knowledge Workers, was used to avoid the over-parameterization and narrow approaches to innovation studies, typical in IS/IT innovation literature.

The formal model was then described. The main outcomes Autonomy and Power defined as the variables associated with agents' performance, respectively for Decision Makers and Knowledge Workers. The matching mechanism was explained as every Knowledge Worker could influence the adoption of a particular IS/IT innovation by the Decision Makers. A discount rate per iteration was explained on the base of fixed depreciation rate that can be explained by means of the knowledge that professionals and top managers have of each other. The transactions only depended on the matching between recommendations and needs of information and represented the normal subsistence operating level of the system. The dynamics and the initial conditions of the system were then explained.

The relationship among agents was based on *a priori* defined distances. A particular time in the simulation was defined to allow for innovation to take place. This way one could compare agents' characteristics before and after intentional innovation (IRI) took place.

Since we were doing an instantiation we first described the model, specified a particular research question and then formulated the research hypotheses. The research question was to assert the validity of the following claim: the power of the knowledge workers in the decision to adopt an IS/IT innovation within an organization varies with the matching level of ideas between them and the top management, while being dependant of the transactions' depreciation rate, leading to a strong fluctuation of power when the environment is unstable.

We conducted the simulations and we showed the results as graphics generated by the formal model codified in Matlab language. Three settings were addressed according to the matching level and within these settings three environments were identified as stable, volatile and highly volatile. The environmental instability was found to be connected to the fixed depreciation rate of the Decision Makers.

Once the results were illustrated, the verification of hypotheses and a discussion around the simulations results were carried out. The broad conclusion is that IS/IT innovation was more efficient in an organization with changing management needs of information, but not very much. If the environment is stable then a negative correlation can be found and a symbiotic relationship is presumed, as both Power and Autonomy augment during the process. The mean efficiency of the innovation process rises as the needs for information increases, but not too much. If they become highly volatile, then the adaptation of the agents is less effective and as such the mean innovation efficiency decreases. Three hypotheses and sub-hypotheses were fully supported, one hypothesis had a sub-hypothesis partially supported and the other two supported, and the last one had one supported and another partially rejected. Thus, we can claim that our specific claim is true.

Finally, we have identified possible avenues drawn from the limitations of the study and positing that the "reality check", or empirical proofing, can bring extended value to the findings of this thesis.

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